

## 8-CHANNEL, ENHANCED MULTIFORMAT, DELTA-SIGMA, DIGITAL-TO-ANALOG CONVERTER

### FEATURES

- Supports DSD and PCM Formats
- Supports TDMCA
- Accepts 16-, 18-, 20- and 24-Bit Audio Data for PCM Format
- Analog Performance ( $V_{CC} = 5\text{ V}$ ):
  - Dynamic Range: 108 dB, Typical
  - SNR: 108 dB, Typical
  - THD+N: 0.0012%, Typical
  - Full-Scale Output: 4  $V_{pp}$ , Typical
- Includes 8× Oversampling Digital Filter for PCM Format:
  - Stopband Attenuation: –60 dB
  - Passband Ripple:  $\pm 0.02\text{ dB}$
- Includes Digital DSD FILTER for DSD Format:
  - Passband: 50 kHz, 70 kHz, 60 kHz at –3 dB
- Sampling Frequency:
  - PCM Mode: 10 kHz to 200 kHz
  - DSD Mode:  $64 \times 44.1\text{ kHz}$
- System Clock:
  - 128  $f_S$ , 192  $f_S$ , 256  $f_S$ , 384  $f_S$ , 512  $f_S$ , 768  $f_S$
- Data Formats:
  - Standard, I<sup>2</sup>S, and Left-Justified for PCM
  - Direct Stream Digital
- User-Programmable Mode Controls:
  - Digital Attenuation
  - Digital De-Emphasis

- Digital Filter Rolloff: Sharp or Slow Soft Mute
- Three Zero Flags
- Dual Supply Operation:
  - 5-V Analog, 3.3-V Digital
- Package: 52-Pin TQFP

### APPLICATIONS

- Universal A/V Players
- SACD Players
- Car Audio Systems
- Other Applications Requiring 24-Bit Audio

### DESCRIPTION

The DSD1608 is a CMOS, monolithic, 8-channel digital-to-analog converter which supports both PCM audio data format and direct stream digital (DSD) audio data format. The device includes an 8× digital interpolation filter and a digital DSD filter with three selectable frequency-response curves, followed by Texas Instruments' enhanced multilevel delta-sigma modulator, which employs 4th-order noise shaping and 8-level amplitude quantization to achieve excellent dynamic performance and improved tolerance to clock jitter. Sampling rates up to 192 kHz for the PCM mode and  $64 \times 44.1\text{ kHz}$  for the DSD mode are supported. A full set of user-programmable functions is accessible through a 4-wire serial control port, which supports register write and read functions. The DSD1608 supports the time-division-multiplexed command and audio data (TDMCA) format. The DSD1608 is available in a 52-pin TQFP package.



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

# DSD1608

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This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

## ORDERING INFORMATION

| PRODUCT    | PACKAGE      | PACKAGE DESIGNATOR | OPERATION TEMPERATURE RANGE | PACKAGE MARKING | ORDERING NUMBER | TRANSPORT MEDIA |
|------------|--------------|--------------------|-----------------------------|-----------------|-----------------|-----------------|
| DSD1608PAH | 52-lead TQFP | PAH                | –25°C to 85°C               | DSD1608         | DSD1608PAH      | Tube            |
|            |              |                    |                             |                 | DSD1608PAHR     | Tape and reel   |

## ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range unless otherwise noted<sup>(1)</sup>

|                                                                                                      |                                     | DSD1608                             |
|------------------------------------------------------------------------------------------------------|-------------------------------------|-------------------------------------|
| Supply voltage                                                                                       | V <sub>CC1</sub> –V <sub>CC7</sub>  | 6.5 V                               |
|                                                                                                      | V <sub>DD1</sub> , V <sub>DD2</sub> | 4 V                                 |
| Supply voltage differences: V <sub>CC1</sub> –V <sub>CC7</sub> , V <sub>DD1</sub> , V <sub>DD2</sub> |                                     | ±0.1 V                              |
| Ground voltage differences: AGND1–6, DGND1, DGND2                                                    |                                     | ±0.1 V                              |
| Digital input voltage: PLRCK, PBCK, PDATA1–PDATA4, DSD1–DSD8, DBCK, DSCK, PSCK, <u>RST</u>           |                                     | –0.3 V to 6.5 V                     |
| Digital input voltage: MC, MS, MDI, ZERO1, ZERO2, ZERO38, MDO                                        |                                     | –0.3 V to (V <sub>DD</sub> + 0.3 V) |
| Analog input voltage                                                                                 |                                     | –0.3 V to (V <sub>CC</sub> + 0.3 V) |
| Input current (any pins except supplies)                                                             |                                     | ±10 mA                              |
| Operating temperature                                                                                |                                     | –40°C to 85°C                       |
| Storage temperature                                                                                  |                                     | –55°C to 150°C                      |
| Junction temperature                                                                                 |                                     | 150°C                               |
| Lead temperature (soldering)                                                                         |                                     | 260°C, 5 s                          |
| Package temperature (IR reflow, peak)                                                                |                                     | 235°C, 10 s                         |

<sup>(1)</sup> Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

## ELECTRICAL CHARACTERISTICS

at T<sub>A</sub> = 25°C, V<sub>DD</sub> = 3.3 V, V<sub>CC</sub> = 5 V; in PCM mode, f<sub>S</sub> = 44.1 kHz, system clock = 256 f<sub>S</sub>, 24-bit data; in DSD mode, f<sub>S</sub> = 2.8224 MHz (= 64 × 44.1 kHz), system clock = 256 × 44.1 kHz, 1-bit data (unless otherwise noted)

| PARAMETER                   |                    | TEST CONDITIONS           | MIN                                                                                                                            | TYP | MAX | UNIT |
|-----------------------------|--------------------|---------------------------|--------------------------------------------------------------------------------------------------------------------------------|-----|-----|------|
| Resolution                  |                    |                           |                                                                                                                                | 24  |     | Bits |
| DATA FORMAT (PCM MODE)      |                    |                           |                                                                                                                                |     |     |      |
| Audio data interface format |                    |                           | Standard, I <sup>2</sup> S, left justified                                                                                     |     |     |      |
| Audio data bit length       |                    |                           | 16-, 18-, 20-, 24-bit selectable                                                                                               |     |     |      |
| Audio data format           |                    |                           | MSB first, 2s complement                                                                                                       |     |     |      |
| f <sub>S</sub>              | Sampling frequency | f <sub>S</sub> = 44.1 kHz | 10                                                                                                                             |     | 200 | kHz  |
| System clock frequency      |                    |                           | 128 f <sub>S</sub> , 192 f <sub>S</sub> , 256 f <sub>S</sub> , 384 f <sub>S</sub> ,<br>512 f <sub>S</sub> , 768 f <sub>S</sub> |     |     |      |
| DATA FORMAT (DSD MODE)      |                    |                           |                                                                                                                                |     |     |      |
| Audio data interface format |                    |                           | Direct stream digital (DSD)                                                                                                    |     |     |      |
| Audio data bit length       |                    |                           | 1 bit                                                                                                                          |     |     |      |
| f <sub>S</sub>              | Sampling frequency | f <sub>S</sub> = 44.1 kHz | 64 f <sub>S</sub>                                                                                                              |     |     | Hz   |
| System clock frequency      |                    | f <sub>S</sub> = 44.1 kHz | 256 f <sub>S</sub> , 384 f <sub>S</sub> , 512 f <sub>S</sub> , 768 f <sub>S</sub>                                              |     |     | kHz  |

<sup>(1)</sup> Pins 50, 51, 34, 33, 37, 38–45, 46–49: PBCK, PLRCK, DSCK, PSCK, DBCK, DSD1–DSD8, PDATA1–PDATA4.

<sup>(2)</sup> Pins 2, 3, 4, 36: MDI, MS, MC, RST.

<sup>(3)</sup> Pins 5–8: MDO, ZERO1, ZERO2, ZERO38.

<sup>(4)</sup> Analog performance specs are measured in the averaging mode using the System Two™ audio measurement system by Audio Precision™.

<sup>(5)</sup> These specs are measured under the condition that the OVR1, OVR0 in mode registers are set to (0,1). (The oversampling rate of the modulator is 64 f<sub>S</sub>.) If the OVR1, OVR0 are (0,0) (32 f<sub>S</sub> oversampling: default), the specs are the same as at f<sub>S</sub> = 96 kHz.

## ELECTRICAL CHARACTERISTICS(continued)

at  $T_A = 25^\circ\text{C}$ ,  $V_{DD} = 3.3\text{ V}$ ,  $V_{CC} = 5\text{ V}$ ; in PCM mode,  $f_S = 44.1\text{ kHz}$ , system clock =  $256 f_S$ , 24-bit data; in DSD mode,  $f_S = 2.8224\text{ MHz}$  ( $= 64 \times 44.1\text{ kHz}$ ), system clock =  $256 \times 44.1\text{ kHz}$ , 1-bit data (unless otherwise noted)

| PARAMETER                                                                       |                     | TEST CONDITIONS                                           | MIN                    | TYP     | MAX   | UNIT            |
|---------------------------------------------------------------------------------|---------------------|-----------------------------------------------------------|------------------------|---------|-------|-----------------|
| DIGITAL INPUT/OUTPUT                                                            |                     |                                                           |                        |         |       |                 |
| Logic family                                                                    |                     |                                                           | TTL-compatible         |         |       |                 |
| V <sub>IH</sub>                                                                 | Input logic level   |                                                           | 2                      |         |       | Vdc             |
| V <sub>IL</sub>                                                                 |                     |                                                           | 0.8                    |         |       |                 |
| I <sub>IH</sub> <sup>(1)</sup>                                                  | Input logic current | V <sub>IN</sub> = V <sub>DD</sub>                         | 10                     |         |       | μA              |
| I <sub>IL</sub> <sup>(1)</sup>                                                  |                     | V <sub>IN</sub> = 0 V                                     | −10                    |         |       |                 |
| I <sub>IH</sub> <sup>(2)</sup>                                                  |                     | V <sub>IN</sub> = V <sub>DD</sub>                         | 65                     |         |       |                 |
| I <sub>IL</sub> <sup>(2)</sup>                                                  |                     | V <sub>IN</sub> = 0 V                                     | −10                    |         |       |                 |
| V <sub>OH</sub> <sup>(3)</sup>                                                  | Output logic level  | I <sub>OH</sub> = −2 mA                                   | 2.4                    |         |       | Vdc             |
| V <sub>OL</sub> <sup>(3)</sup>                                                  |                     | I <sub>OL</sub> = +2 mA                                   | 1                      |         |       |                 |
| DYNAMIC PERFORMANCE <sup>(4)</sup> (PCM MODE)                                   |                     |                                                           |                        |         |       |                 |
| THD+N at V <sub>OUT</sub> = 0 dB                                                |                     | f <sub>S</sub> = 44.1 kHz                                 | 0.0012%                |         |       |                 |
|                                                                                 |                     | f <sub>S</sub> = 96 kHz                                   | 0.0015%                |         |       |                 |
|                                                                                 |                     | f <sub>S</sub> = 192 kHz <sup>(5)</sup>                   | 0.002%                 |         |       |                 |
| THD+N at V <sub>OUT</sub> = −3 dB                                               |                     | f <sub>S</sub> = 44.1 kHz                                 | 0.0012%                | 0.0018% |       |                 |
|                                                                                 |                     | f <sub>S</sub> = 96 kHz                                   | 0.0015%                |         |       |                 |
|                                                                                 |                     | f <sub>S</sub> = 192 kHz <sup>(5)</sup>                   | 0.002%                 |         |       |                 |
| Dynamic range                                                                   |                     | EIAJ, A-weighted, f <sub>S</sub> = 44.1 kHz               | 104                    | 108     |       | dB              |
|                                                                                 |                     | EIAJ, A-weighted, f <sub>S</sub> = 96 kHz                 | 108                    |         |       |                 |
|                                                                                 |                     | EIAJ, A-weighted, f <sub>S</sub> = 192 kHz <sup>(5)</sup> | 107                    |         |       |                 |
| Signal-to-noise ratio                                                           |                     | EIAJ, A-weighted, f <sub>S</sub> = 44.1 kHz               | 104                    | 108     |       | dB              |
|                                                                                 |                     | EIAJ, A-weighted, f <sub>S</sub> = 96 kHz                 | 108                    |         |       |                 |
|                                                                                 |                     | EIAJ, A-weighted, f <sub>S</sub> = 192 kHz <sup>(5)</sup> | 107                    |         |       |                 |
| Channel separation                                                              |                     | f <sub>S</sub> = 44.1 kHz                                 | 101                    | 104     |       | dB              |
|                                                                                 |                     | f <sub>S</sub> = 96 kHz                                   | 104                    |         |       |                 |
|                                                                                 |                     | f <sub>S</sub> = 192 kHz <sup>(5)</sup>                   | 103                    |         |       |                 |
| Level linearity error                                                           |                     | V <sub>OUT</sub> = −90 dB                                 | ±0.5                   |         |       | dB              |
| DYNAMIC PERFORMANCE <sup>(4)</sup> DSD MODE (at f <sub>S</sub> = 64 × 44.1 kHz) |                     |                                                           |                        |         |       |                 |
| THD+N at V <sub>OUT</sub> = 0 dB                                                |                     |                                                           | 0.0012%                |         |       |                 |
| Dynamic range                                                                   |                     | EIAJ, A-weighted                                          | 108                    |         |       | dB              |
| Signal-to-noise ratio                                                           |                     | EIAJ, A-weighted                                          | 108                    |         |       | dB              |
| Channel separation                                                              |                     |                                                           | 104                    |         |       | dB              |
| Level linearity error                                                           |                     | V <sub>OUT</sub> = −90 dB                                 | ±0.5                   |         |       | dB              |
| DC ACCURACY                                                                     |                     |                                                           |                        |         |       |                 |
| Gain error                                                                      |                     |                                                           | ±1                     | ±6      | % FSR |                 |
| Gain mismatch, channel-to-channel                                               |                     |                                                           | ±1                     | ±3      | % FSR |                 |
| Bipolar zero error                                                              |                     | V <sub>OUT</sub> = 0.5 V <sub>CC</sub> at BPZ             | ±30                    | ±60     | mV    |                 |
| ANALOG OUTPUT                                                                   |                     |                                                           |                        |         |       |                 |
| Output voltage                                                                  |                     | Full scale (0 dB)                                         | 80% of V <sub>CC</sub> |         |       | V <sub>pp</sub> |
| Center voltage                                                                  |                     |                                                           | 50% of V <sub>CC</sub> |         |       | Vdc             |
| Load impedance                                                                  |                     | AC load                                                   | 4                      |         |       | kΩ              |

(1) Pins 50, 51, 34, 33, 37, 38–45, 46–49: PBCK, PLRCK, DSCK, PSCK, DBCK, DSD1–DSD8, PDATA1–PDATA4.

(2) Pins 2, 3, 4, 36: MDI, MS, MC, RST.

(3) Pins 5–8: MDO, ZERO1, ZERO2, ZERO38.

(4) Analog performance specs are measured in the averaging mode using the System Two™ audio measurement system by Audio Precision™.

(5) These specs are measured under the condition that the OVR1, OVR0 in mode registers are set to (0,1). (The oversampling rate of the modulator is  $64 f_S$ .) If the OVR1, OVR0 are (0,0) ( $32 f_S$  oversampling: default), the specs are the same as at  $f_S = 96\text{ kHz}$ .

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## ELECTRICAL CHARACTERISTICS(continued)

at  $T_A = 25^\circ\text{C}$ ,  $V_{DD} = 3.3\text{ V}$ ,  $V_{CC} = 5\text{ V}$ ; in PCM mode,  $f_S = 44.1\text{ kHz}$ , system clock =  $256 f_S$ , 24-bit data; in DSD mode,  $f_S = 2.8224\text{ MHz}$  ( $= 64 \times 44.1\text{ kHz}$ ), system clock =  $256 \times 44.1\text{ kHz}$ , 1-bit data (unless otherwise noted)

| PARAMETER                                       |                | TEST CONDITIONS                                | MIN                  | TYP                  | MAX | UNIT |
|-------------------------------------------------|----------------|------------------------------------------------|----------------------|----------------------|-----|------|
| DIGITAL FILTER PERFORMANCE                      |                |                                                |                      |                      |     |      |
| 8× INTERPOLATION FILTER (SHARP ROLL OFF FILTER) |                |                                                |                      |                      |     |      |
| Pass band                                       |                | ±0.02 dB                                       |                      | 0.454 f <sub>S</sub> |     | Hz   |
| Pass band                                       |                | −3 dB                                          |                      | 0.487 f <sub>S</sub> |     | Hz   |
| Stop band                                       |                |                                                | 0.546 f <sub>S</sub> |                      |     | Hz   |
| Pass-band ripple                                |                |                                                |                      | ±0.02                |     | dB   |
| Stop-band attenuation                           |                | Stop band = 0.546 f <sub>S</sub>               | −60                  |                      |     | dB   |
| Delay Time                                      |                |                                                |                      | 23/f <sub>S</sub>    |     | s    |
| 8× INTERPOLATION FILTER (SLOW ROLL OFF FILTER)  |                |                                                |                      |                      |     |      |
| Pass band                                       |                | −0.5 dB                                        |                      | 0.308 f <sub>S</sub> |     | Hz   |
| Pass band                                       |                | −3 dB                                          |                      | 0.432 f <sub>S</sub> |     | Hz   |
| Stop band                                       |                |                                                | 0.832 f <sub>S</sub> |                      |     | Hz   |
| Pass-band ripple                                |                | 0.308 f <sub>S</sub>                           |                      | ±0.5                 |     | dB   |
| Stop-band attenuation                           |                | 0.832 f <sub>S</sub>                           | −58                  |                      |     | dB   |
| Delay time                                      |                |                                                |                      | 23/f <sub>S</sub>    |     | s    |
| DE-EMPHASIS FILTER (PCM MODE ONLY)              |                |                                                |                      |                      |     |      |
| De-emphasis error                               |                | At f <sub>S</sub> = 32 kHz, 44.1 kHz or 48 kHz |                      | ±0.1                 |     | dB   |
| DSD FILTER (FILTER-1)                           |                |                                                |                      |                      |     |      |
| Pass band                                       |                | At −3 dB                                       |                      | 50                   |     | kHz  |
| Stop-band attenuation                           |                | At 100 kHz                                     |                      | −18                  |     | dB   |
| DSD FILTER (FILTER-2)                           |                |                                                |                      |                      |     |      |
| Pass band                                       |                | At −3 dB                                       |                      | 70                   |     | kHz  |
| Stop-band attenuation                           |                | At 100 kHz                                     |                      | −9.8                 |     | dB   |
| DSD FILTER (FILTER-3)                           |                |                                                |                      |                      |     |      |
| Pass band                                       |                | At −3 dB                                       |                      | 60                   |     | kHz  |
| Stop-band attenuation                           |                | At 100 kHz                                     |                      | −17                  |     | dB   |
| INTERNAL ANALOG FILTER PERFORMANCE              |                |                                                |                      |                      |     |      |
| Frequency response                              |                | At 20 kHz                                      |                      | −0.02                |     | dB   |
|                                                 |                | At 44 kHz                                      |                      | −0.1                 |     |      |
|                                                 |                | At 50 kHz                                      |                      | −0.12                |     |      |
|                                                 |                | At 100 kHz                                     |                      | −0.5                 |     |      |
| POWER SUPPLY REQUIREMENTS                       |                |                                                |                      |                      |     |      |
| V <sub>DD</sub>                                 | Voltage range  |                                                | 3                    | 3.3                  | 3.6 | Vdc  |
| V <sub>CC</sub>                                 |                |                                                | 4.5                  | 5.0                  | 5.5 |      |
| I <sub>DD</sub>                                 | Supply current | f <sub>S</sub> = 44.1 kHz                      |                      | 28                   | 40  | mA   |
|                                                 |                | f <sub>S</sub> = 192 kHz                       |                      | 74                   |     |      |
|                                                 |                | DSD mode                                       |                      | 45                   |     |      |
| I <sub>CC</sub>                                 |                | f <sub>S</sub> = 44.1 kHz                      |                      | 36                   | 50  |      |
|                                                 |                | f <sub>S</sub> = 192 kHz                       |                      | 38                   |     |      |
| Power dissipation                               |                | f <sub>S</sub> = 44.1 kHz                      |                      | 270                  | 380 | mW   |
|                                                 |                | f <sub>S</sub> = 192 kHz                       |                      | 430                  |     |      |

(1) Pins 50, 51, 34, 33, 37, 38–45, 46–49: PBCK, PLRCK, DSCK, PSCK, DBCK, DSD1–DSD8, PDATA1–PDATA4.

(2) Pins 2, 3, 4, 36: MDI, MS, MC, RST.

(3) Pins 5–8: MDO, ZERO1, ZERO2, ZERO38.

(4) Analog performance specs are measured in the averaging mode using the System Two™ audio measurement system by Audio Precision™.

(5) These specs are measured under the condition that the OVR1, OVR0 in mode registers are set to (0,1). (The oversampling rate of the modulator is  $64 f_S$ .) If the OVR1, OVR0 are (0,0) ( $32 f_S$  oversampling: default), the specs are the same as at  $f_S = 96\text{ kHz}$ .

## ELECTRICAL CHARACTERISTICS(continued)

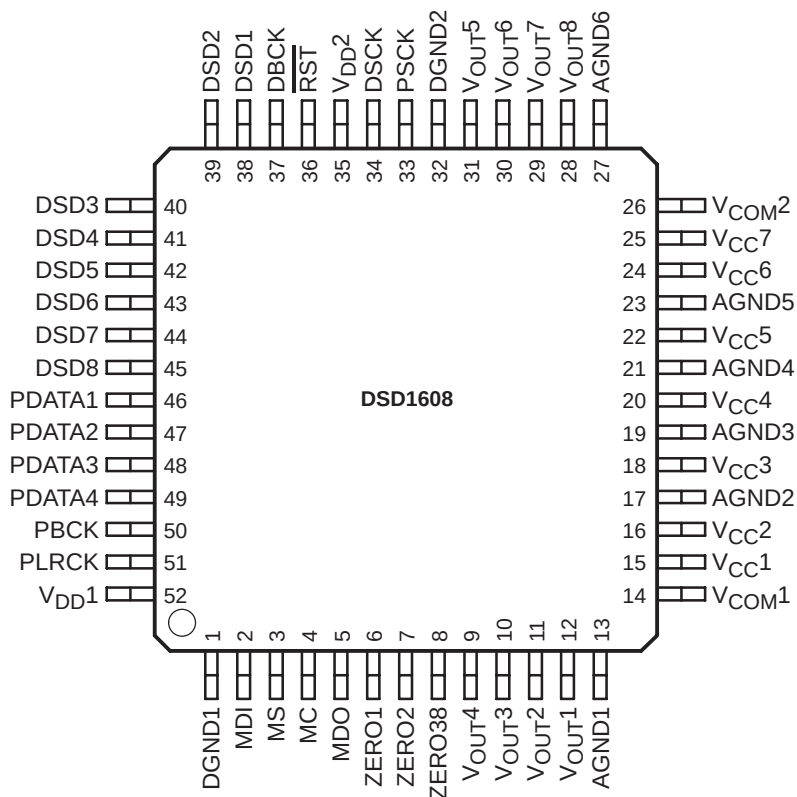
at  $T_A = 25^\circ\text{C}$ ,  $V_{DD} = 3.3\text{ V}$ ,  $V_{CC} = 5\text{ V}$ ; in PCM mode,  $f_S = 44.1\text{ kHz}$ , system clock =  $256 f_S$ , 24-bit data; in DSD mode,  $f_S = 2.8224\text{ MHz}$  ( $= 64 \times 44.1\text{ kHz}$ ), system clock =  $256 \times 44.1\text{ kHz}$ , 1-bit data (unless otherwise noted)

| PARAMETER                        | TEST CONDITIONS | MIN | TYP | MAX | UNIT               |
|----------------------------------|-----------------|-----|-----|-----|--------------------|
| <b>TEMPERATURE RANGE</b>         |                 |     |     |     |                    |
| Operating temperature            |                 | -25 |     | 85  | $^\circ\text{C}$   |
| $\theta_{JA}$ Thermal resistance | 52 TQFP         |     | 70  |     | $^\circ\text{C/W}$ |

- (1) Pins 50, 51, 34, 33, 37, 38–45, 46–49: PBCK, PLRCK, DSCK, PSCK, DBCK, DSD1–DSD8, PDATA1–PDATA4.
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## PIN ASSIGNMENTS

**PAH PACKAGE  
(TOP VIEW)**



# DSD1608

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## Terminal Functions

| TERMINAL<br>NAME | NO. | I/O | DESCRIPTION                                                                                               |
|------------------|-----|-----|-----------------------------------------------------------------------------------------------------------|
| AGND1            | 13  | —   | Analog ground                                                                                             |
| AGND2            | 17  | —   | Analog ground                                                                                             |
| AGND3            | 19  | —   | Analog ground                                                                                             |
| AGND4            | 21  | —   | Analog ground                                                                                             |
| AGND5            | 23  | —   | Analog ground                                                                                             |
| AGND6            | 27  | —   | Analog ground                                                                                             |
| DBCK             | 37  | I   | DSD audio data bit clock input (DSD) <sup>(3)</sup>                                                       |
| DGND1            | 1   | —   | Digital ground                                                                                            |
| DGND2            | 32  | —   | Digital ground                                                                                            |
| DSCK             | 34  | I   | System clock input (DSD). Input frequency is 256, 384, 512 or 768 f <sub>S</sub> <sup>(3)</sup>           |
| DSD1             | 38  | I   | DSD audio data input for V <sub>OUT1</sub> (DSD) <sup>(3)</sup>                                           |
| DSD2             | 39  | I   | DSD audio data input for V <sub>OUT2</sub> (DSD) <sup>(3)</sup>                                           |
| DSD3             | 40  | I   | DSD audio data input for V <sub>OUT3</sub> (DSD) <sup>(3)</sup>                                           |
| DSD4             | 41  | I   | DSD audio data input for V <sub>OUT4</sub> (DSD) <sup>(3)</sup>                                           |
| DSD5             | 42  | I   | DSD audio data input for V <sub>OUT5</sub> (DSD) <sup>(3)</sup>                                           |
| DSD6             | 43  | I   | DSD audio data input for V <sub>OUT6</sub> (DSD) <sup>(3)</sup>                                           |
| DSD7             | 44  | I   | DSD audio data input for V <sub>OUT7</sub> (DSD) <sup>(3)</sup>                                           |
| DSD8             | 45  | I   | DSD audio data input for V <sub>OUT8</sub> (DSD) <sup>(3)</sup>                                           |
| MC               | 4   | I   | Mode control clock input <sup>(1)</sup>                                                                   |
| MDI              | 2   | I   | Mode control data input <sup>(1)</sup>                                                                    |
| MDO              | 5   | O   | Mode control read back data output <sup>(4)</sup>                                                         |
| MS               | 3   | I   | Chip select for mode control <sup>(1)</sup>                                                               |
| PBCK             | 50  | I   | Audio data bit clock input (PCM) <sup>(3)</sup>                                                           |
| PDATA1           | 46  | I   | Serial audio data input for V <sub>OUT1</sub> and V <sub>OUT2</sub> (PCM) <sup>(3)</sup>                  |
| PDATA2           | 47  | I   | Serial audio data input for V <sub>OUT3</sub> and V <sub>OUT4</sub> (PCM) <sup>(3)</sup>                  |
| PDATA3           | 48  | I   | Serial audio data input for V <sub>OUT5</sub> and V <sub>OUT6</sub> (PCM) <sup>(3)</sup>                  |
| PDATA4           | 49  | I   | Serial audio data input for V <sub>OUT7</sub> and V <sub>OUT8</sub> (PCM) <sup>(3)</sup>                  |
| PLRCK            | 51  | I   | Audio data L/R clock input (PCM) <sup>(3)</sup>                                                           |
| PSCK             | 33  | I   | System clock input (PCM). Input frequency is 128, 192, 256, 384, 512 or 768 f <sub>S</sub> <sup>(3)</sup> |
| RST              | 36  | I   | System reset, active LOW <sup>(2)</sup>                                                                   |
| VCC1             | 15  | —   | Analog power supply, 5 V                                                                                  |
| VCC2             | 16  | —   | Analog power supply, 5 V                                                                                  |
| VCC3             | 18  | —   | Analog power supply, 5 V                                                                                  |
| VCC4             | 20  | —   | Analog power supply, 5 V                                                                                  |
| VCC5             | 22  | —   | Analog power supply, 5 V                                                                                  |
| VCC6             | 24  | —   | Analog power supply, 5 V                                                                                  |
| VCC7             | 25  | —   | Analog power supply, 5 V                                                                                  |
| VCOM1            | 14  | O   | Common voltage output 1. This pin should be bypassed with a 10-μF capacitor to AGND.                      |

<sup>(1)</sup> Schmitt-trigger input with internal pulldown.

<sup>(2)</sup> Schmitt-trigger input with internal pulldown, 5-V tolerant.

<sup>(3)</sup> Schmitt-trigger input, 5-V tolerant.

<sup>(4)</sup> 3-state output.

### Terminal Functions (continued)

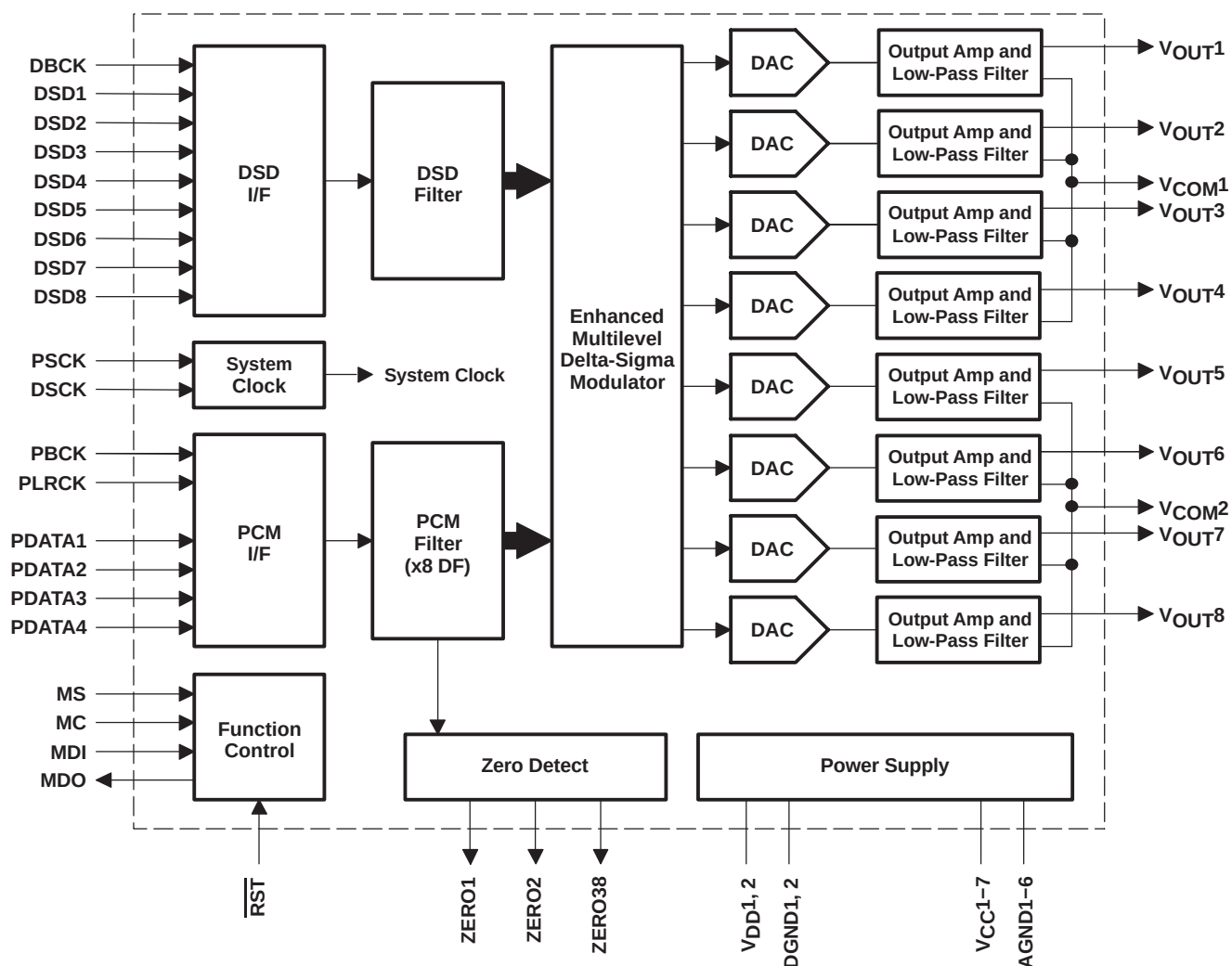
| TERMINAL<br>NAME  | NO. | I/O | DESCRIPTION                                                                          |
|-------------------|-----|-----|--------------------------------------------------------------------------------------|
| V <sub>COM2</sub> | 26  | O   | Common voltage output 2. This pin should be bypassed with a 10-μF capacitor to AGND. |
| V <sub>DD1</sub>  | 52  | —   | Digital power supply, 3.3 V                                                          |
| V <sub>DD2</sub>  | 35  | —   | Digital power supply, 3.3 V                                                          |
| V <sub>OUT1</sub> | 12  | O   | Voltage output for audio signal corresponding to L-channel on PDATA1 or DSD1         |
| V <sub>OUT2</sub> | 11  | O   | Voltage output for audio signal corresponding to R-channel on PDATA1 or DSD2         |
| V <sub>OUT3</sub> | 10  | O   | Voltage output for audio signal corresponding to L-channel on PDATA2 or DSD3         |
| V <sub>OUT4</sub> | 9   | O   | Voltage output for audio signal corresponding to R-channel on PDATA2 or DSD4         |
| V <sub>OUT5</sub> | 31  | O   | Voltage output for audio signal corresponding to L-channel on PDATA3 or DSD5         |
| V <sub>OUT6</sub> | 30  | O   | Voltage output for audio signal corresponding to R-channel on PDATA3 or DSD6         |
| V <sub>OUT7</sub> | 29  | O   | Voltage output for audio signal corresponding to L-channel on PDATA4 or DSD7         |
| V <sub>OUT8</sub> | 28  | O   | Voltage output for audio signal corresponding to R-channel on PDATA4 or DSD8         |
| ZERO1             | 6   | O   | Zero data flag for V <sub>OUT1</sub>                                                 |
| ZERO2             | 7   | O   | Zero data flag for V <sub>OUT2</sub>                                                 |
| ZERO38            | 8   | O   | Zero data flag for V <sub>OUT3</sub> –V <sub>OUT8</sub>                              |

- (1) Schmitt-trigger input with internal pulldown.
- (2) Schmitt-trigger input with internal pulldown, 5-V tolerant.
- (3) Schmitt-trigger input, 5-V tolerant.
- (4) 3-state output.

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## BLOCK DIAGRAM





## TYPICAL PERFORMANCE CURVES

### DIGITAL FILTER—PCM MODE

#### 8× Interpolation Filter (De-Emphasis Off)

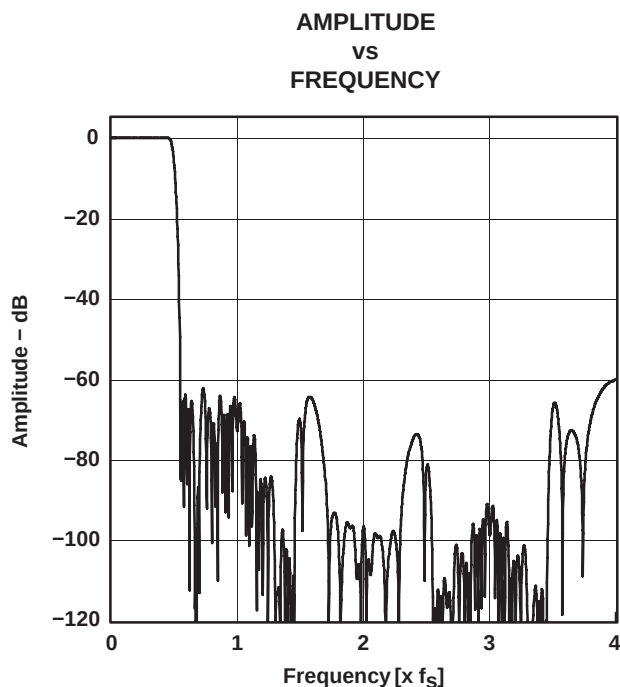


Figure 1. Frequency Response (Sharp Rolloff)

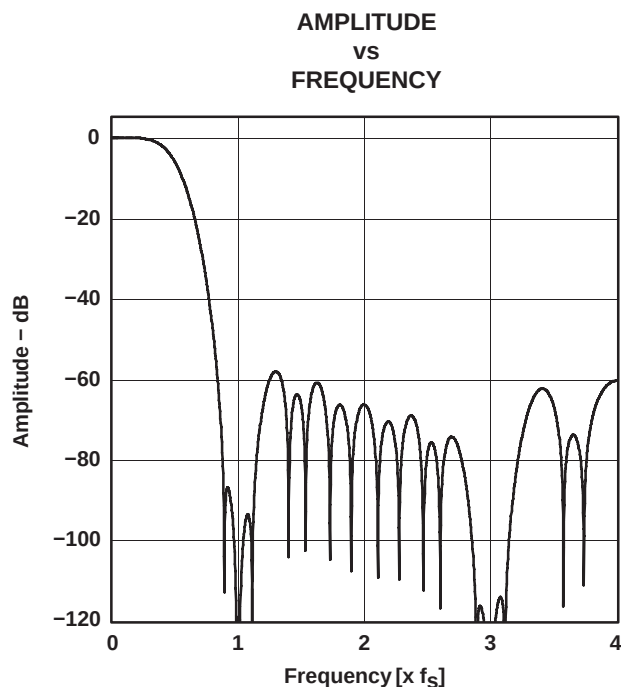


Figure 2. Frequency Response (Slow Rolloff)

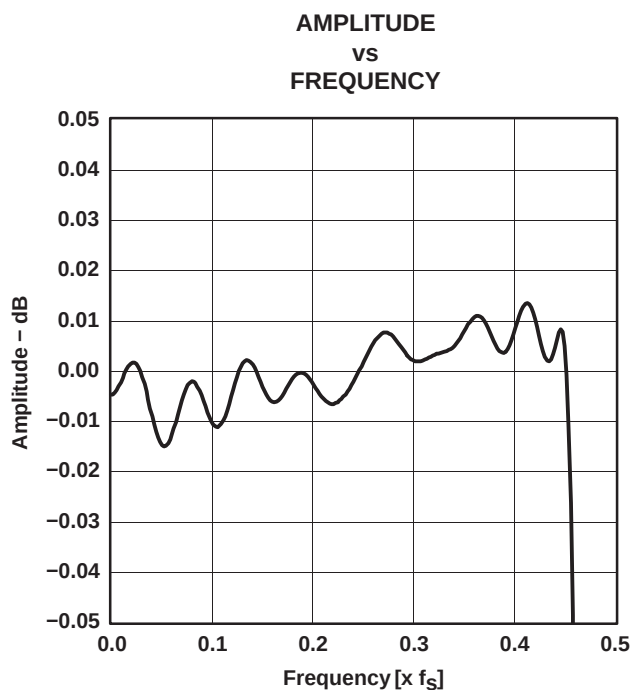


Figure 3. Pass-Band Ripple (Sharp Rolloff)

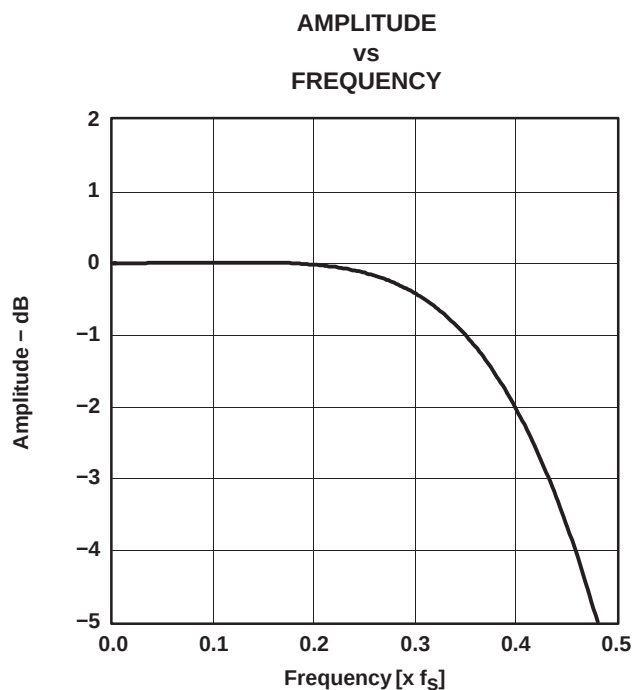


Figure 4. Frequency Response (Slow Rolloff)

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## De-Emphasis Curves

DE-EMPHASIS LEVEL  
VS  
FREQUENCY

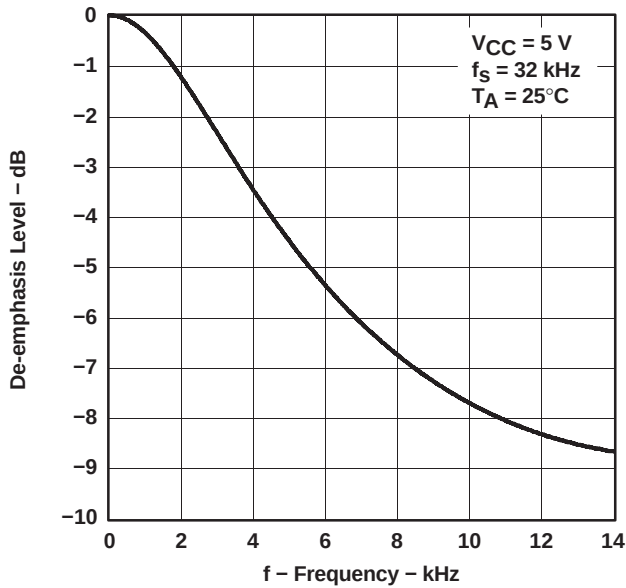


Figure 5

DE-EMPHASIS ERROR  
VS  
FREQUENCY

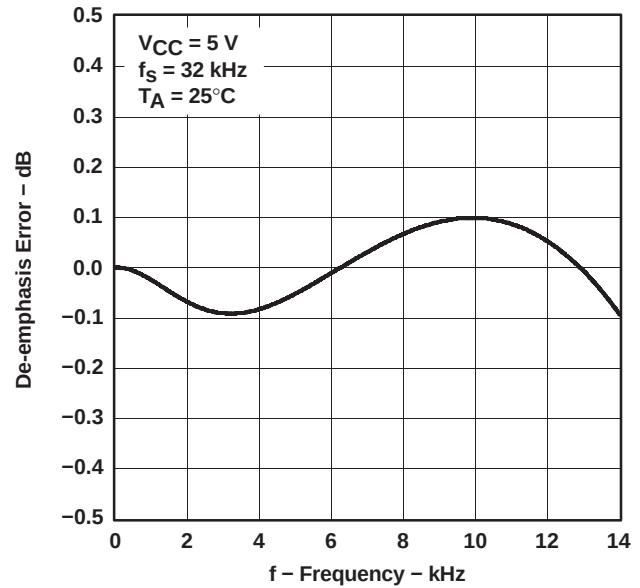


Figure 6

DE-EMPHASIS LEVEL  
VS  
FREQUENCY

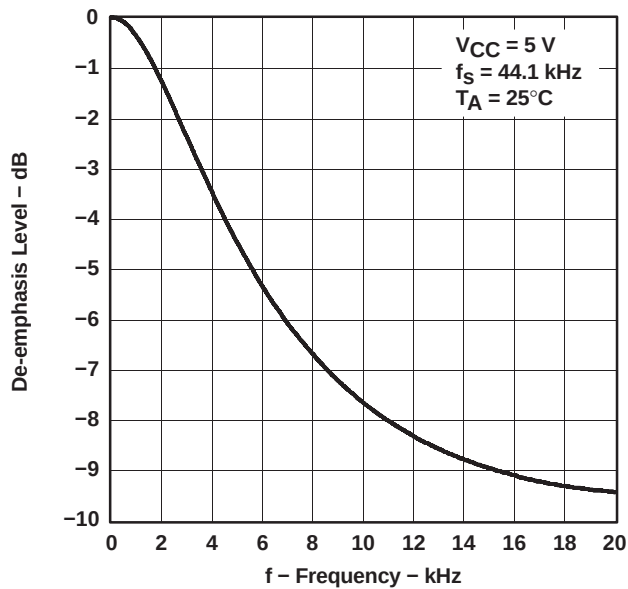


Figure 7

DE-EMPHASIS ERROR  
VS  
FREQUENCY

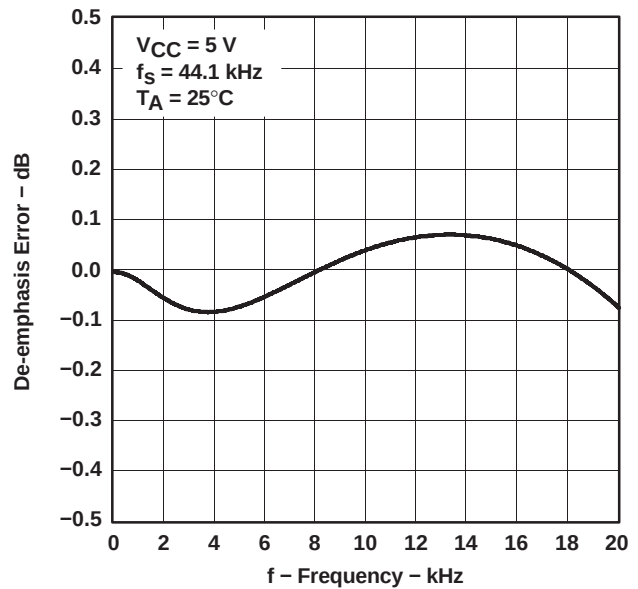
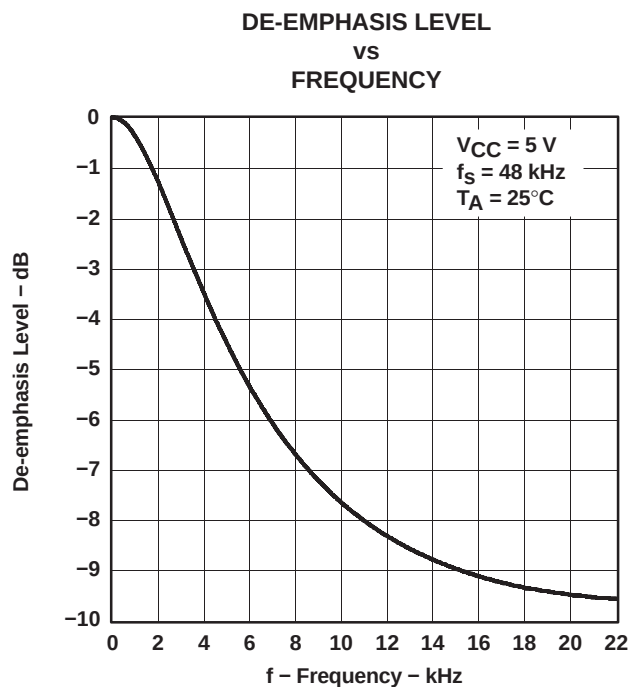
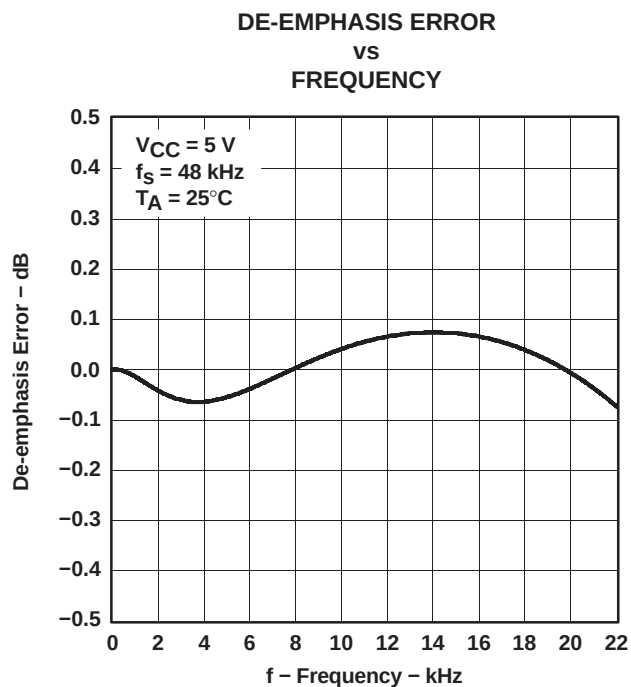


Figure 8

## De-Emphasis Curves (Continued)



**Figure 9**



**Figure 10**

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## ANALOG DYNAMIC PERFORMANCE

### Supply Voltage Characteristics

TOTAL HARMONIC DISTORTION + NOISE (–3 dB)  
VS  
SUPPLY VOLTAGE

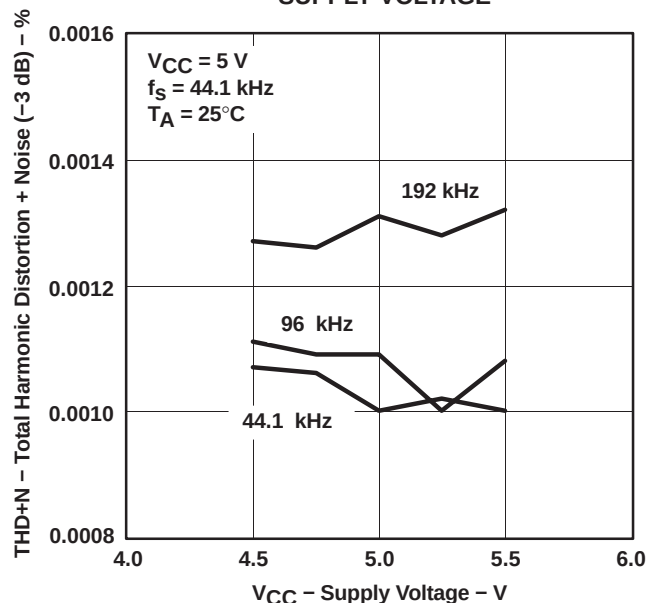


Figure 11

DYNAMIC RANGE  
VS  
SUPPLY VOLTAGE

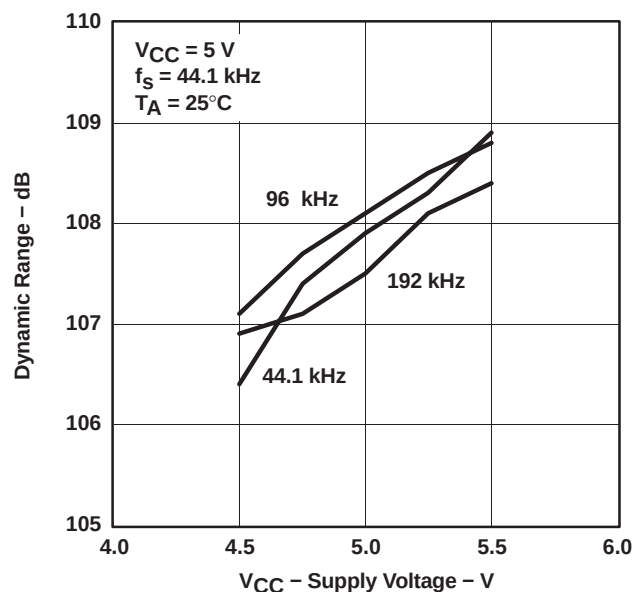


Figure 12

SNR  
VS  
SUPPLY VOLTAGE

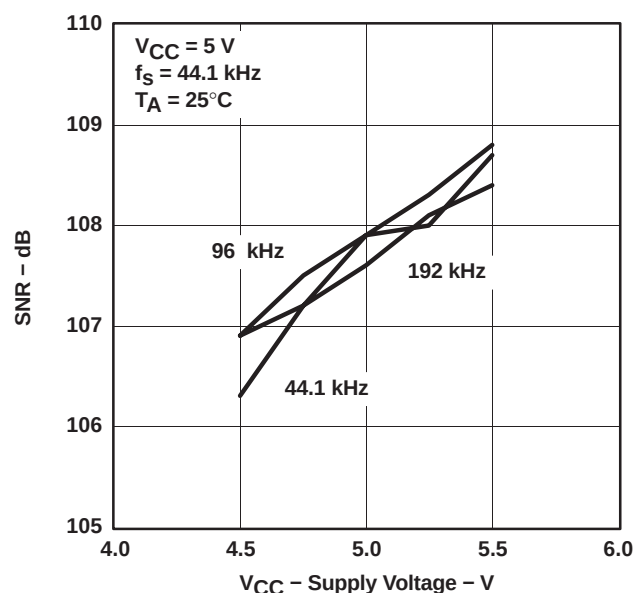


Figure 13

CHANNEL SEPARATION  
VS  
SUPPLY VOLTAGE

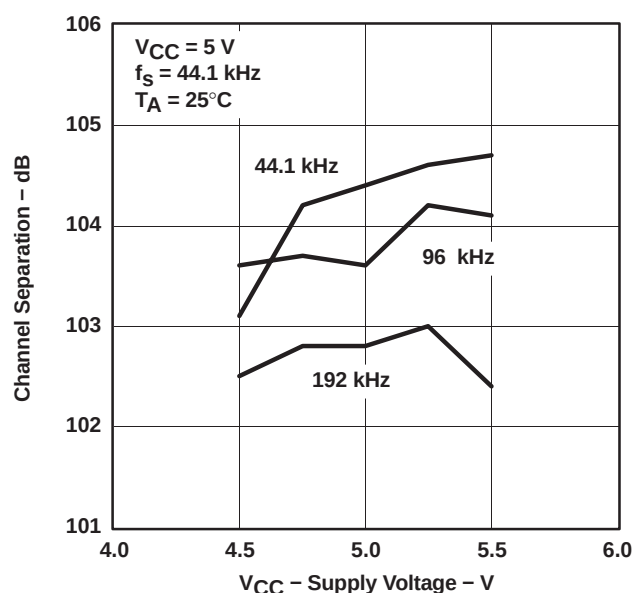
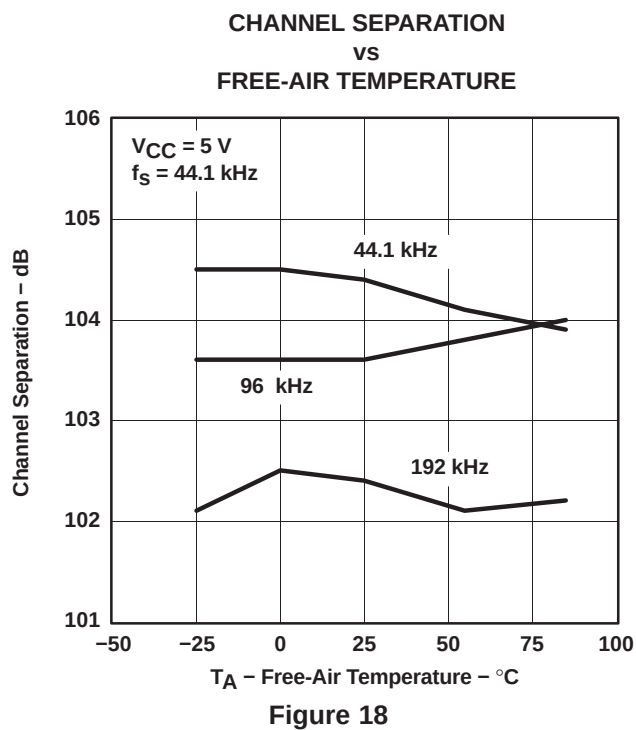
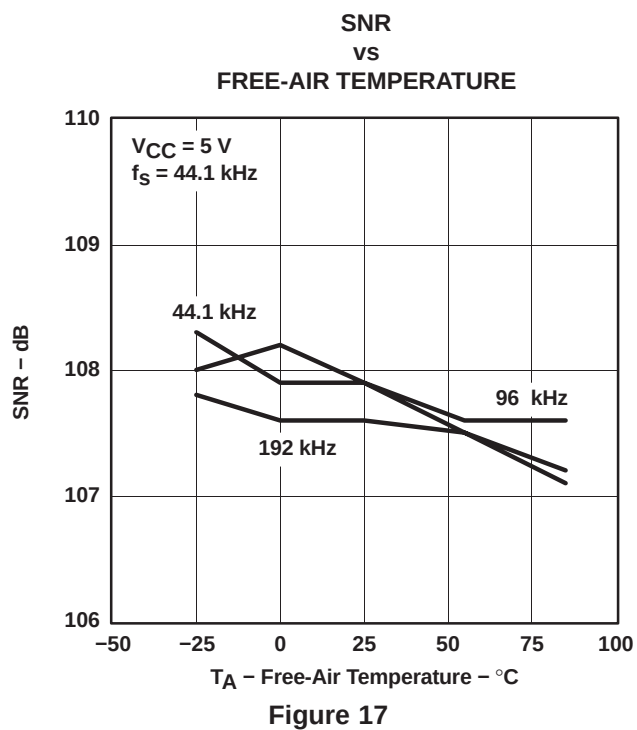
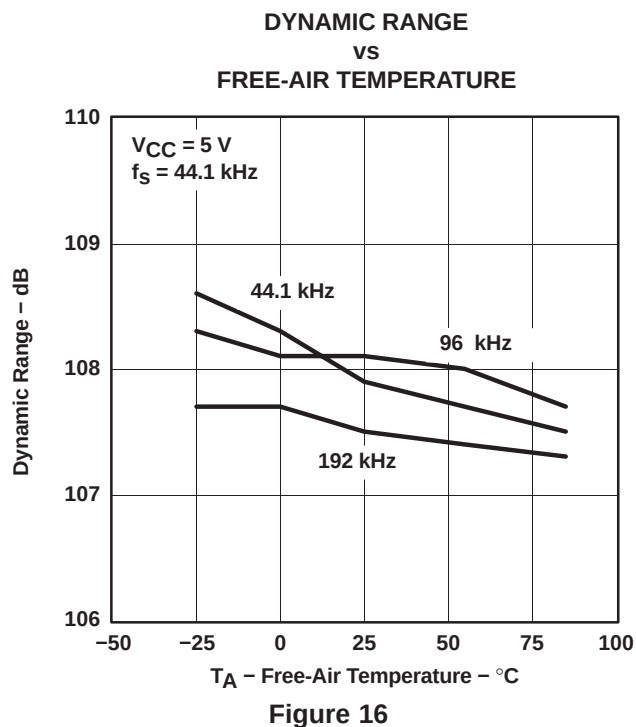
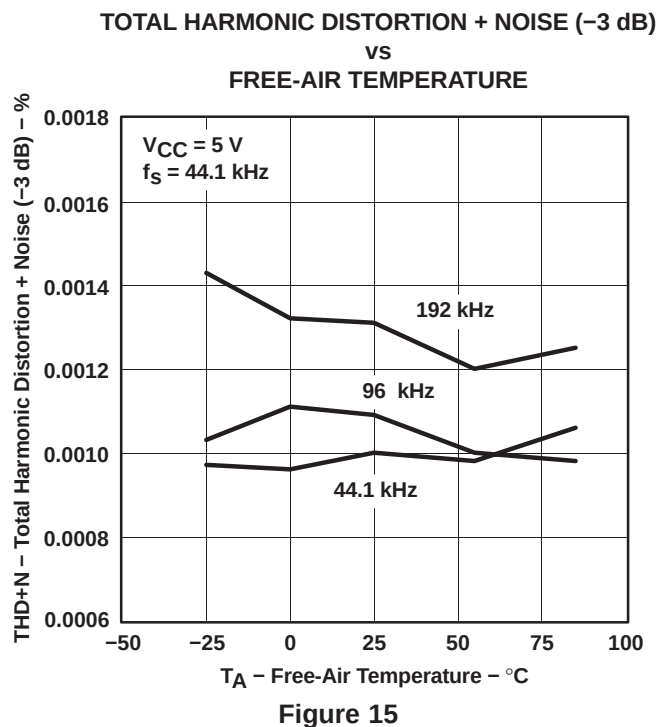


Figure 14

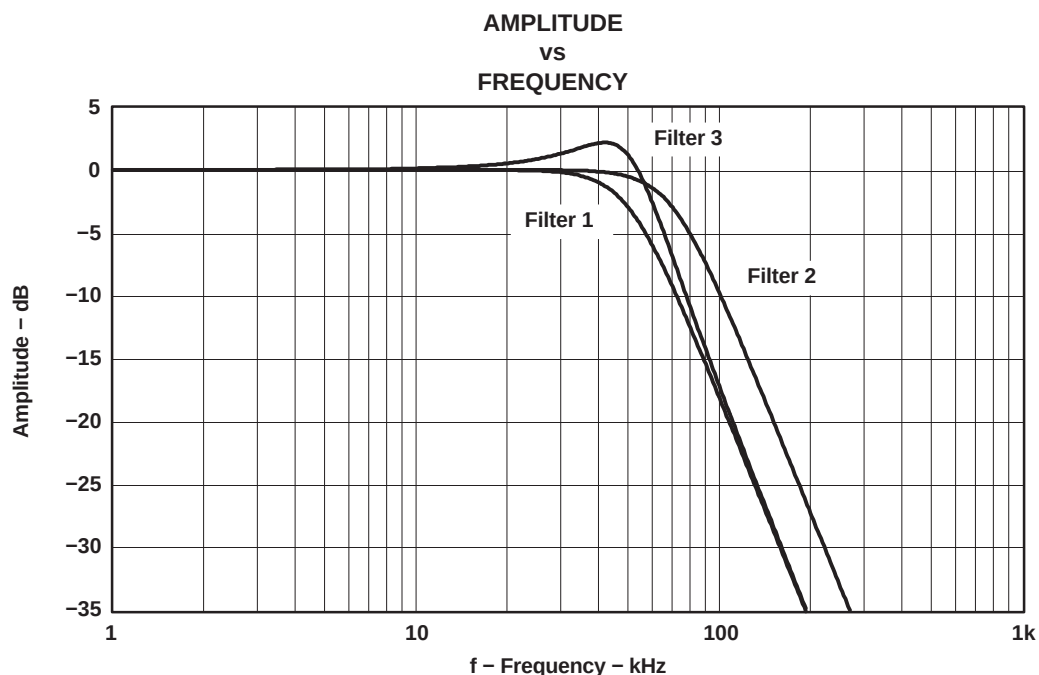
All specifications at TA = +25°C, VCC = 5.0 V, VDD = 3.3 V, fS = 44.1 kHz, system clock = 384 fS and 24-bit data, unless otherwise noted

## Temperature Characteristics



All specifications at  $T_A = +25^\circ\text{C}$ ,  $V_{CC} = 5.0\text{ V}$ ,  $V_{DD} = 3.3\text{ V}$ ,  $f_S = 44.1\text{ kHz}$ , system clock =  $384 f_S$  and 24-bit data, unless otherwise noted

## DIGITAL FILTER—DSD MODE



**Figure 19**

## SYSTEM CLOCK AND RESET FUNCTIONS

### System clock input

The DSD1608 requires a system clock for operating the digital interpolation filter, digital DSD filter and multilevel delta-sigma modulator. The system clock is applied to PSCK (pin 33) in the PCM mode and to DSCK (pin 34) in the DSD mode. When CKCE (control register 10, B3) is not set to 1, the system clock is applied to PSCK in the DSD mode. The DSD1608 has a system clock detection circuit. Table 1 shows examples of system clock frequencies for common audio sampling rates.

Figure 20 shows the timing requirements for the system clock input. For optimal performance, it is important to use a clock source with low phase jitter and noise. Texas Instruments' PLL1700 multiclock generator is an excellent choice for providing the DSD1608 system.

In the PCM mode, the oversampling rate of digital filter is 4 $\times$  when a 128- $f_S$  or 192- $f_S$  system clock is applied to the DSD1608. When a 256- $f_S$ , 384- $f_S$ , 512- $f_S$ , or 768- $f_S$  system clock is applied, the oversampling rate is 8 $\times$ .

**Table 1. System Clock Rates for Common Audio Sampling Frequencies**

| MODE | SAMPLING<br>FREQUENCY | SYSTEM CLOCK FREQUENCY ( $f_{SCLK}$ ) (MHz) |           |           |           |           |           |
|------|-----------------------|---------------------------------------------|-----------|-----------|-----------|-----------|-----------|
|      |                       | 128 $f_S$                                   | 192 $f_S$ | 256 $f_S$ | 384 $f_S$ | 512 $f_S$ | 768 $f_S$ |
| PCM  | 16kHz                 | 2.0480                                      | 3.0720    | 4.0960    | 6.1440    | 8.1920    | 12.2880   |
|      | 32kHz                 | 4.0960                                      | 6.1440    | 8.1920    | 12.2880   | 16.3840   | 24.5760   |
|      | 44.1kHz               | 5.6488                                      | 8.4672    | 11.2896   | 16.9344   | 22.5792   | 33.8688   |
|      | 48kHz                 | 6.1440                                      | 9.2160    | 12.2880   | 18.4320   | 24.5760   | 36.8640   |
|      | 88.2kHz               | 11.2896                                     | 16.9344   | 22.5792   | 33.8688   | 45.1584   | 67.7376   |
|      | 96kHz                 | 12.2880                                     | 18.4320   | 24.5760   | 36.8640   | 49.1520   | 73.7280   |
|      | 192kHz                | 24.5760                                     | 36.8640   | See Note  | See Note  | See Note  | See Note  |
| DSD  | 64 $\times$ 44.1kHz   | —                                           | —         | 11.2896   | 16.9344   | 22.5792   | 33.8688   |

NOTE: This system clock is not supported for the given sampling frequency.

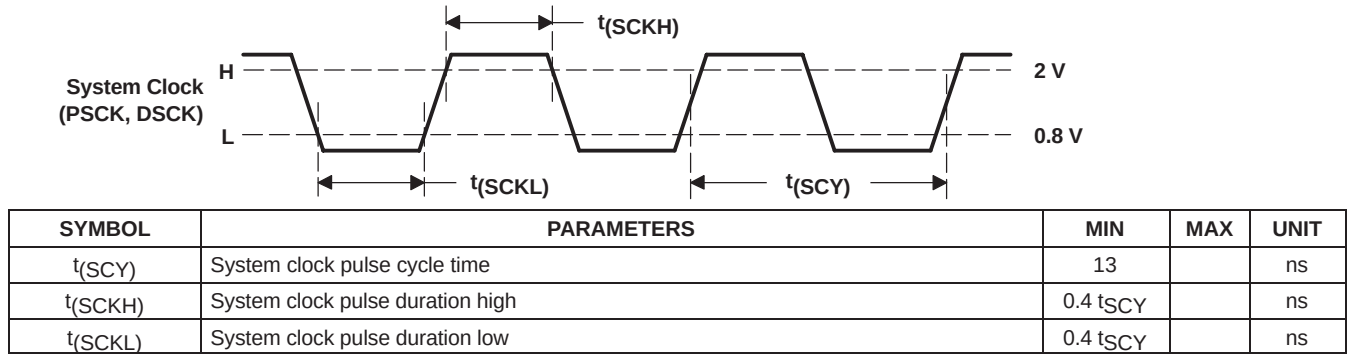


Figure 20. System Clock Input Timing

### Power-On and External Reset Functions

The DSD1608 includes a power-on reset function. Figure 21 shows the operation of this function. With  $V_{DD} > 2$  V, the power-on reset function is enabled. The initialization sequence requires 1024 system clocks from the time  $V_{DD} > 2$  V. After the initialization period, the DSD1608 is set to its reset default state, as described in the *mode control register* section of this data sheet. The DSD1608 also includes an external reset capability using the  $\overline{RST}$  input (pin 36). This allows an external controller or master reset circuit to force the DSD1608 to initialize to its reset state. Figure 22 shows the external reset operation and timing. The  $\overline{RST}$  pin is set to logic 0 for a minimum of 20 ns. When the  $\overline{RST}$  pin is set to a logic 0 state, the DSD1608 is initialized. The  $\overline{RST}$  pin is then set to a logic 1 state, thus starting the initialization sequence, which requires 1024 system clock periods.

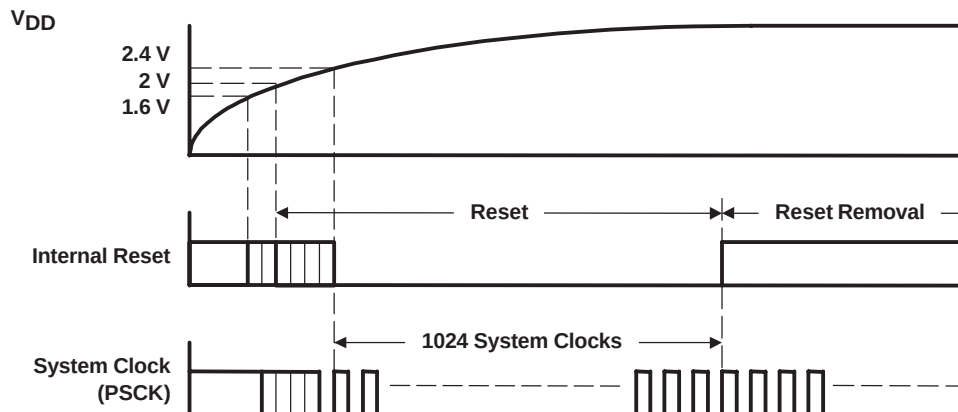
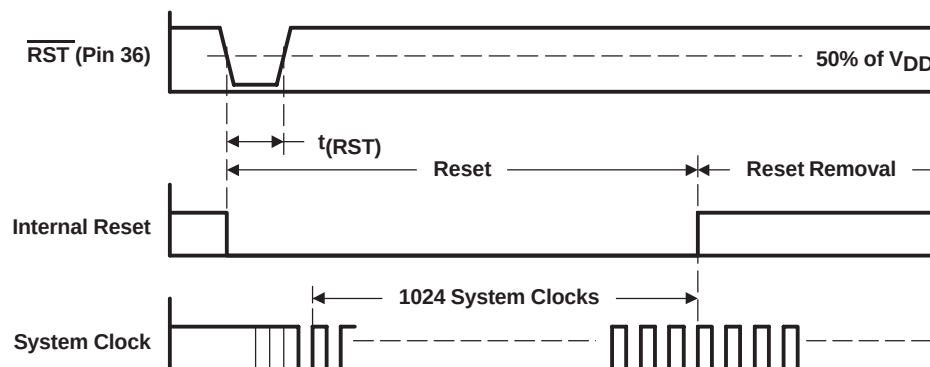


Figure 21. Power-On Reset Timing



| SYMBOL   | PARAMETERS               | MIN | MAX | UNIT |
|----------|--------------------------|-----|-----|------|
| $t(RST)$ | Reset pulse duration low | 20  |     | ns   |

Figure 22. External Reset Timing

## DSD1608

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### Audio Serial Interface

The DSD1608 has two audio serial interface ports: PCM audio interface port and DSD audio interface port.

In the PCM mode, the audio interface is a 3-wire serial port. It includes PLRCK (pin 51), PBCK (pin 50), and PDATA1–PDATA4 (pins 46–49). PBCK is the serial audio bit clock, and it is used to clock the serial data present on PDATA1–4 into the audio interface serial shift register. Serial data is clocked into the DSD1608 on the rising edge of PBCK. PLRCK is the serial audio left/right word clock. It is used to latch serial data into the serial audio interface internal registers.

The DSD1608 requires the synchronization of PLRCK to the system clock, but does not require a specific phase relation between PLRCK and system clock.

If the relationship between PLRCK and system clock changes more than  $\pm 6$  PBCK, internal operation is initialized within  $1/f_S$  and analog outputs are forced to  $0.5 V_{CC}$  until re-synchronization between PLRCK and the system clock is completed.

In the DSD mode, the audio interface is a 2-wire serial port. DBCK (pin 37) is the serial audio bit clock, and it is used to clock the individual direct stream digital (DSD) audio data on DSD1–DSD8 (pins 38–45). DSD data is clocked into the DSD1608 on the rising edge of DBCK. DBCK must be synchronous with the system clock, but does not require a specific phase relation to the system clock. DBCK is operated at the sampling frequency  $f_S$ ; the  $f_S$  of DSD is  $64 \times 44.1$  kHz, nominal.

### Audio Data Formats and Timing

In the PCM mode, the DSD1608 supports industry-standard audio data formats, including standard,  $I^2S$ , and left-justified. The data formats are shown in Figure 23. Data formats are selected using the format bits, FMT[2:0], in control register 10. The default data format is 24-bit standard format. All formats require binary 2s complement, MSB-first audio data. Figure 24 shows a detailed timing diagram for the serial audio interface.

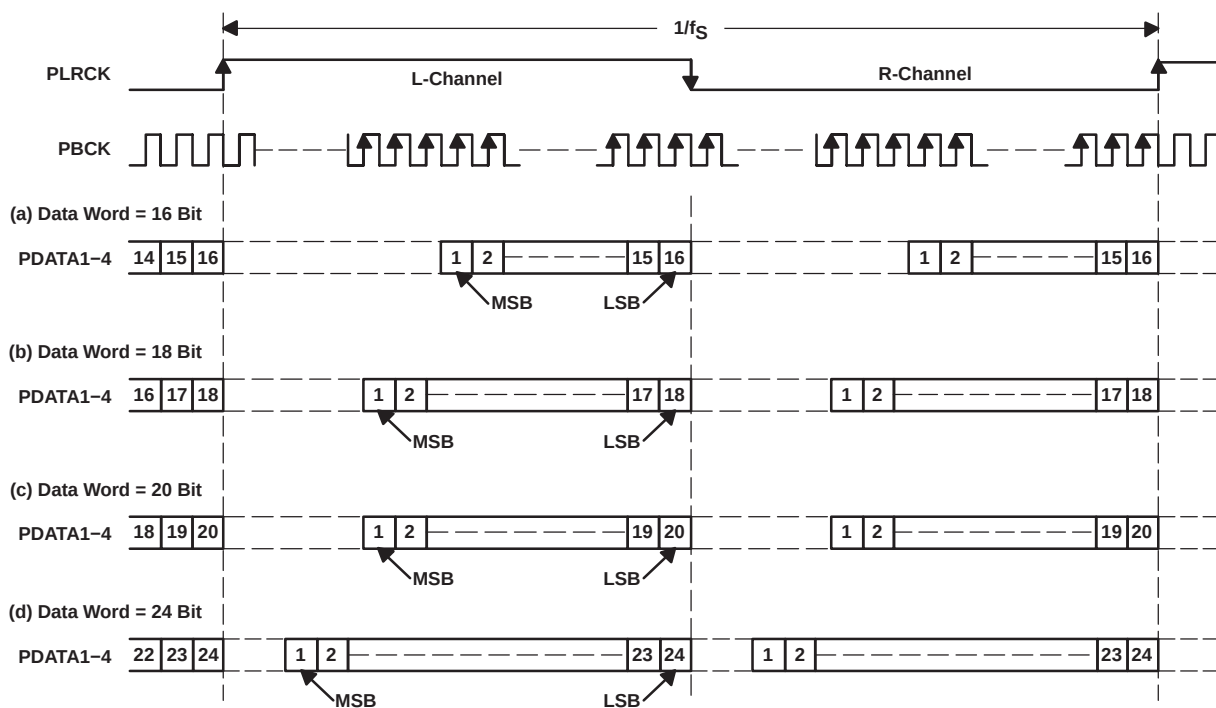
In the DSD mode, the DSD1608 supports a DSD audio data format. The data formats are shown in Figure 25. Figure 26 shows a detailed timing diagram for the DSD audio data interface.

### Serial Control Interface

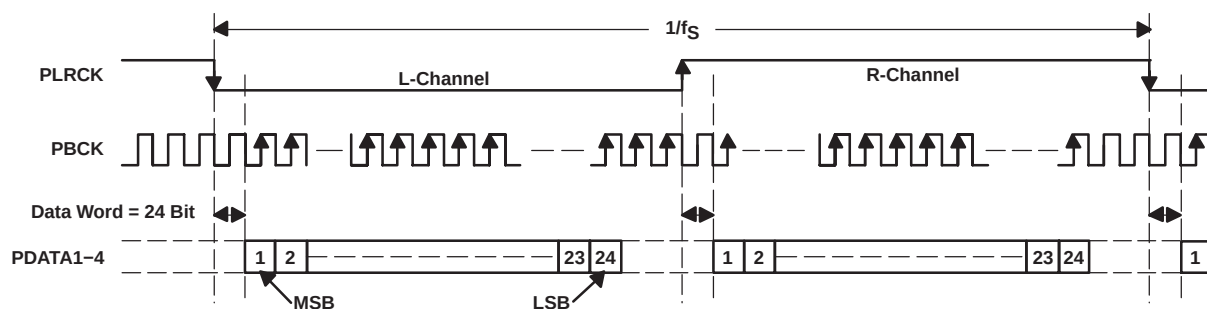
The serial control interface is a 4-wire serial port which operates completely asynchronously from the serial audio interface and the system clock. The serial control interface is used to access the on-chip mode registers. The control interface includes MDI (pin 2), MDO (pin 5), MC (pin 4), and MS (pin 3). MDI is the serial data input, used to program the mode registers. MDO is the serial data output, used to read back the values of the mode registers. MC is the serial bit clock, used to shift data into the control port, and MS is the chip select for the control port.



(1) STD Format: L-Channel = H, R-Channel = L



(2) IIS Format: L-Channel = L, R-Channel = H



(3) Left Justified Format: L-Channel = H, R-Channel = L

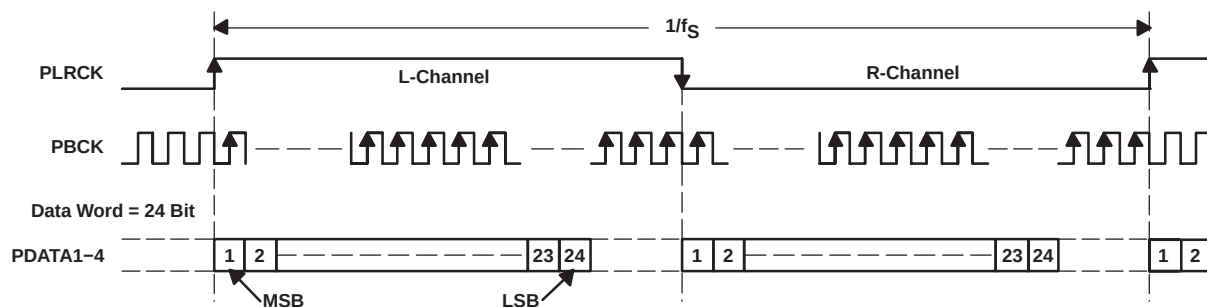
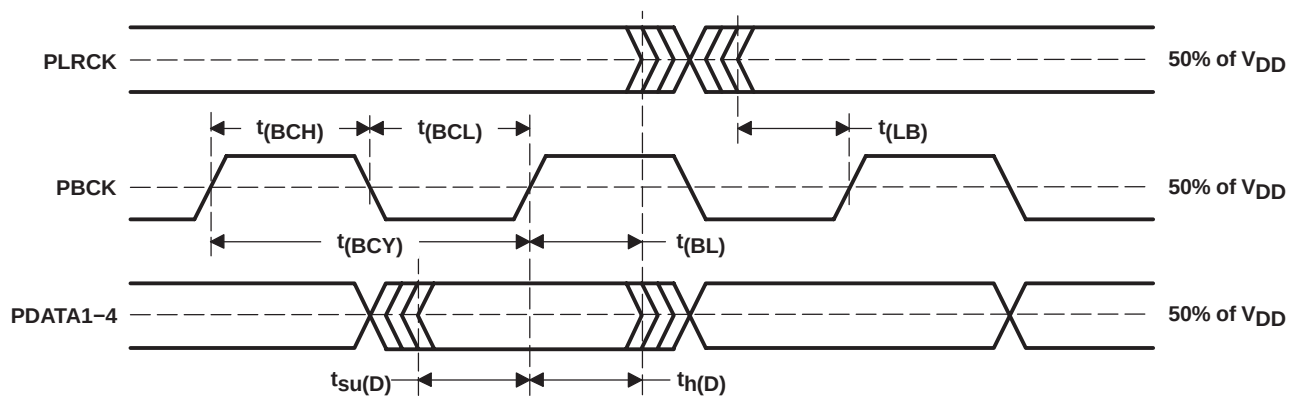


Figure 23. PCM Data Format

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| SYMBOL      | PARAMETERS                     | MIN | MAX | UNIT |
|-------------|--------------------------------|-----|-----|------|
| $t_{(BCY)}$ | PBCK pulse cycle time          | 70  |     | ns   |
| $t_{(BCH)}$ | PBCK high-level time           | 30  |     | ns   |
| $t_{(BCL)}$ | PBCK low-level time            | 30  |     | ns   |
| $t_{(BL)}$  | PBCK rising edge to PLRCK edge | 10  |     | ns   |
| $t_{(LB)}$  | PLRCK edge to PBCK rising edge | 10  |     | ns   |
| $t_{su(D)}$ | PDATA1-4 setup time            | 10  |     | ns   |
| $t_{h(D)}$  | PDATA1-4 hold time             | 10  |     | ns   |

Figure 24. Timing for PCM Audio Interface

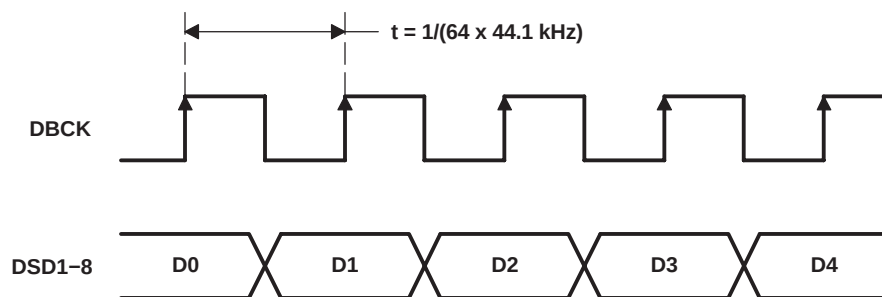
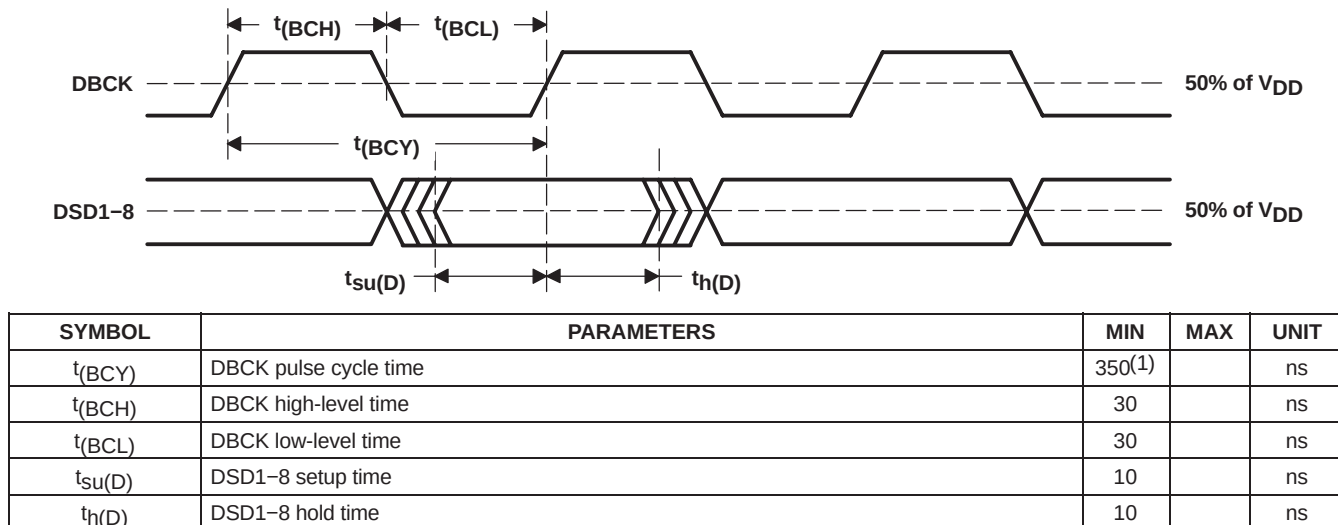


Figure 25. Normal Data Output Form From DSD Decoder



(1) 2.8224 MHz = 64 × 44.1 kHz; this value is specified as a sampling rate of DSD.

Figure 26. Timing for DSD Audio Interface

### Register Read/Write Operation

All read/write operations for the serial control port use 16-bit data words. Figure 27 shows the control data word format. The most significant bit is the read/write (R/W) bit. For write operations, the R/W bit must be set to 0. For read operations, the R/W bit must be set to 1. There are seven bits, labeled IDX[6:0], that set the register index (or address) for the read or write operations. The least significant eight bits, D[7:0], contain the data to be written to the register specified by IDX[6:0] or to be read from the register specified by IDX[6:0].

Figure 28 shows the functional timing diagram for writing or reading the serial control port. MS is held at a logic 1 state until a register needs to be written or read. To start the register write or read cycle, MS is set to logic 0. Sixteen clocks are then provided on MC, corresponding to the 16 bits of the control data word on MDI and read back data on MDO. After the eighth clock cycle has completed, the data from indexed mode control register appears on MDO in read operation. After the sixteenth clock cycle has completed, the data is latched into the indexed mode control register in write operations. To write or read subsequent data, MS must be set to 1 once.

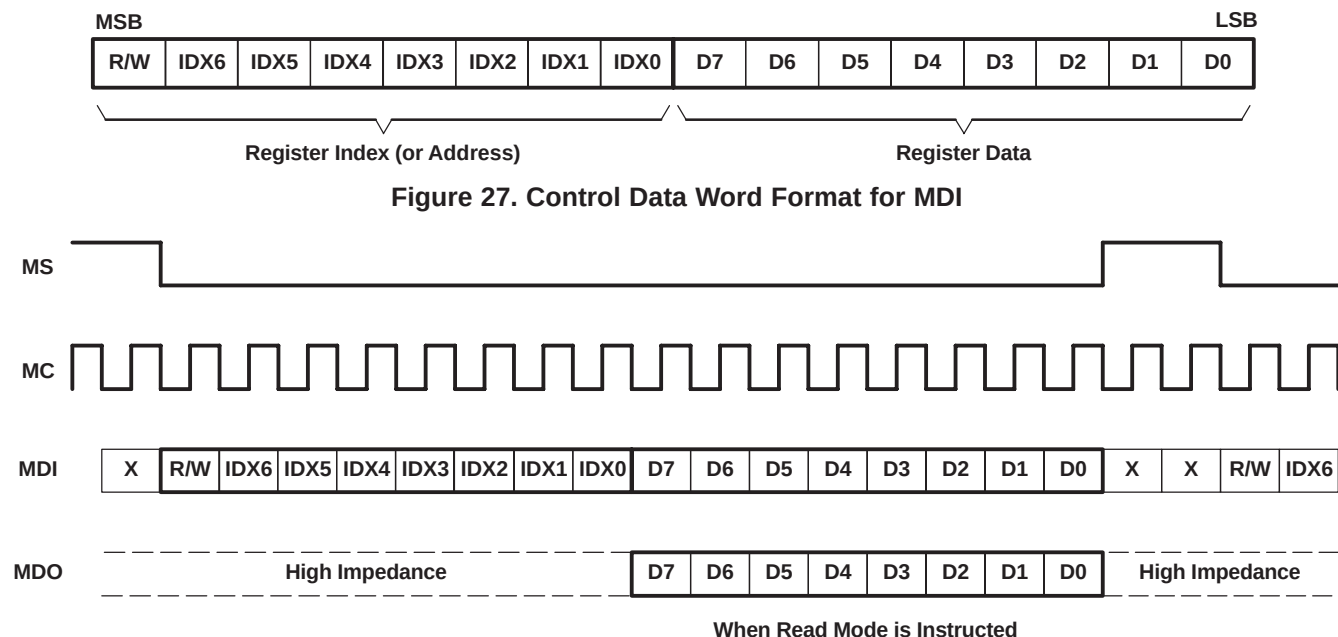


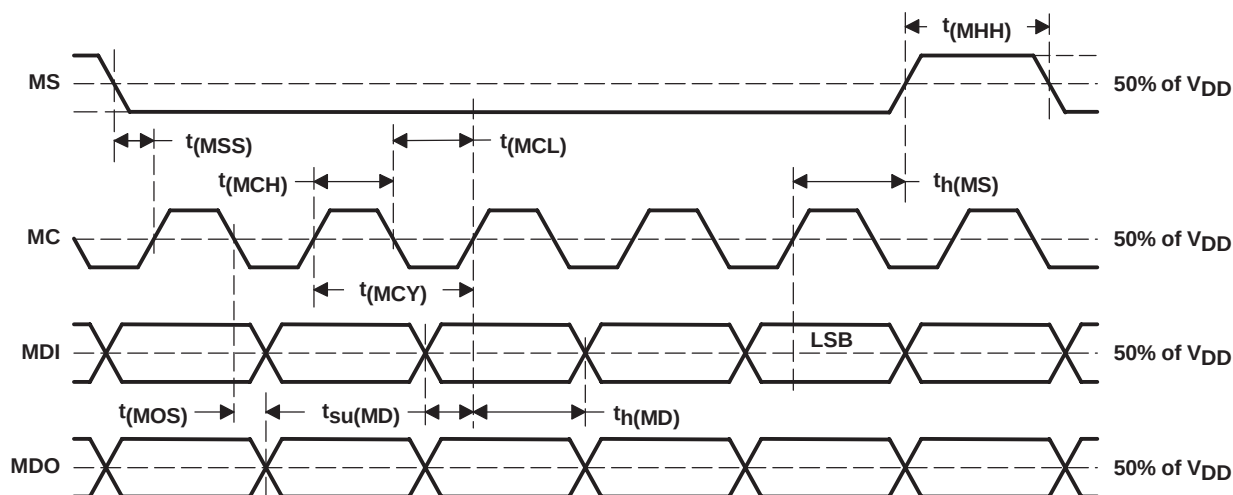
Figure 28. Serial Control Format

## DSD1608

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### Control Interface Timing Requirements

Figure 29 shows a detailed timing diagram for the serial control interface. These timing parameters are critical for proper control port operation.



| SYMBOL       | PARAMETERS                      | MIN | MAX | UNIT |
|--------------|---------------------------------|-----|-----|------|
| $t(MCY)$     | MC pulse cycle time             | 100 |     | ns   |
| $t(MCL)$     | MC low level time               | 40  |     | ns   |
| $t(MCH)$     | MC high level time              | 40  |     | ns   |
| $t(MHH)$     | MS high level time              | 80  |     | ns   |
| $t(MSS)$     | MS falling edge to MC rise edge | 15  |     | ns   |
| $t_h(MS)$    | MS hold time <sup>(1)</sup>     | 15  |     | ns   |
| $t_h(MD)$    | MDI hold time                   | 15  |     | ns   |
| $t_{su}(MD)$ | MDI setup time                  | 15  |     | ns   |
| $t(MOS)$     | MC falling edge to MDO stable   |     | 30  | ns   |

<sup>(1)</sup> MC rising edge for LSB-to-MS rising edge.

**Figure 29. Control Interface Timing**

### MODE CONTROL REGISTERS

#### User-Programmable Mode Controls

The DSD1608 includes a number of user programmable functions which are accessed via control registers. The registers are programmed using the serial control interface which was previously discussed in this data sheet. Table 2 lists the available mode control functions, along with their reset default conditions and associated register index.

#### Register Map

The mode control register map is shown in Table 3. Each register includes an index (or address) indicated by the ID<sub>X</sub>[6:0] bits B[14:8].

**Table 2. User-Programmable Mode Controls**

| FUNCTION                                                       | RESET DEFAULT                     | REGISTER | BIT(S)               | PCM | DSD |
|----------------------------------------------------------------|-----------------------------------|----------|----------------------|-----|-----|
| Digital attenuation control, 0 dB to $-\infty$ in 0.5 dB steps | 0dB, no attenuation               | 0–7      | AT1[7:0] to AT8[7:0] | √   | √   |
| Soft mute control                                              | Mute disabled                     | 8        | MUT[8:1]             | √   | √   |
| DAC operation control                                          | DAC1 to DAC8 enabled              | 9        | DAC[8:1]             | √   | √   |
| Audio data format control                                      | 24-bit standard format            | 10       | FMT[2:0]             | √   |     |
| Clock select control                                           | Disabled                          | 10       | CKCE                 |     | √   |
| Attenuation rate select                                        | $8/f_S$                           | 10       | ATS                  | √   | √   |
| Rolloff control for 8× digital filter                          | Sharp rolloff                     | 10       | FLT                  | √   |     |
| De-emphasis function control                                   | De-emphasis disabled              | 11       | DM12, -34, -56, -78  | √   |     |
| De-emphasis sample rate control                                | 44.1kHz                           | 11       | DMF[1:0]             | √   |     |
| Over sampling rate control ( $64 f_S$ or $128 f_S$ )           | $64 f_S$ oversampling             | 11       | OVR[1:0]             | √   |     |
| Output phase select                                            | Normal phase                      | 12       | DRV12, -34, -56, -78 | √   | √   |
| Zero flag polarity select                                      | High                              | 12       | ZREV                 | √   |     |
| Zero flag output pin select                                    | CH1/2 flags separately selectable | 12       | AZRO                 | √   |     |
| DSD mode control                                               | PCM mode                          | 12       | DSD                  |     | √   |
| System reset                                                   | Not operated                      | 12       | SRST                 | √   | √   |
| DSD filter select                                              | Filter 1                          | 13, 14   | FS1[1:0] to FS8[1:0] |     | √   |
| Zero flag status (read-only)                                   | —                                 | 16       | ZERO[8:1]            | √   |     |
| Device ID (at TDMCA)                                           | —                                 | 17       | ID[4:0]              | √   | √   |

**Table 3. Mode Control Register Map**

|             | B15 | B14 | B13 | B12 | B11 | B10 | B9 | B8 | B7    | B6    | B5    | B4    | B3    | B2    | B1    | B0    |
|-------------|-----|-----|-----|-----|-----|-----|----|----|-------|-------|-------|-------|-------|-------|-------|-------|
| Register 0  | R/W | 0   | 0   | 0   | 0   | 0   | 0  | 0  | AT17  | AT16  | AT15  | AT14  | AT13  | AT12  | AT11  | AT10  |
| Register 1  | R/W | 0   | 0   | 0   | 0   | 0   | 0  | 1  | AT27  | AT26  | AT25  | AT24  | AT23  | AT22  | AT21  | AT20  |
| Register 2  | R/W | 0   | 0   | 0   | 0   | 0   | 1  | 0  | AT37  | AT36  | AT35  | AT34  | AT33  | AT32  | AT31  | AT30  |
| Register 3  | R/W | 0   | 0   | 0   | 0   | 0   | 1  | 1  | AT47  | AT46  | AT45  | AT44  | AT43  | AT42  | AT41  | AT40  |
| Register 4  | R/W | 0   | 0   | 0   | 0   | 1   | 0  | 0  | AT57  | AT56  | AT55  | AT54  | AT53  | AT52  | AT51  | AT50  |
| Register 5  | R/W | 0   | 0   | 0   | 0   | 1   | 0  | 1  | AT67  | AT66  | AT65  | AT64  | AT63  | AT62  | AT61  | AT60  |
| Register 6  | R/W | 0   | 0   | 0   | 0   | 1   | 1  | 0  | AT77  | AT76  | AT75  | AT74  | AT73  | AT72  | AT71  | AT70  |
| Register 7  | R/W | 0   | 0   | 0   | 0   | 1   | 1  | 1  | AT87  | AT86  | AT85  | AT84  | AT83  | AT82  | AT81  | AT80  |
| Register 8  | R/W | 0   | 0   | 0   | 1   | 0   | 0  | 0  | MUT8  | MUT7  | MUT6  | MUT5  | MUT4  | MUT3  | MUT2  | MUT1  |
| Register 9  | R/W | 0   | 0   | 0   | 1   | 0   | 0  | 1  | DAC8  | DAC7  | DAC6  | DAC5  | DAC4  | DAC3  | DAC2  | DAC1  |
| Register 10 | R/W | 0   | 0   | 0   | 1   | 0   | 1  | 0  | RSV   | FLT   | ATS   | RSV   | CKCE  | FMT2  | FMT1  | FMT0  |
| Register 11 | R/W | 0   | 0   | 0   | 1   | 0   | 1  | 1  | OVR1  | OVR0  | DMF1  | DMF0  | DM78  | DM56  | DM34  | DM12  |
| Register 12 | R/W | 0   | 0   | 0   | 1   | 1   | 0  | 0  | SRST  | DSD   | AZRO  | ZREV  | DRV78 | DRV56 | DRV34 | DRV12 |
| Register 13 | R/W | 0   | 0   | 0   | 1   | 1   | 0  | 1  | FS41  | FS40  | FS31  | FS30  | FS21  | FS20  | FS11  | FS10  |
| Register 14 | R/W | 0   | 0   | 0   | 1   | 1   | 1  | 0  | FS81  | FS80  | FS71  | FS70  | FS61  | FS60  | FS51  | FS50  |
| Register 16 | R   | 0   | 0   | 1   | 0   | 0   | 0  | 0  | ZERO8 | ZERO7 | ZERO6 | ZERO5 | ZERO4 | ZERO3 | ZERO2 | ZERO1 |
| Register 17 | R   | 0   | 0   | 1   | 0   | 0   | 0  | 1  | RSV   | RSV   | RSV   | ID4   | ID3   | ID2   | ID1   | ID0   |

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## Register Definitions

|            | B15 | B14 | B13 | B12 | B11 | B10 | B9 | B8 | B7   | B6   | B5   | B4   | B3   | B2   | B1   | B0   |
|------------|-----|-----|-----|-----|-----|-----|----|----|------|------|------|------|------|------|------|------|
| Register 0 | R/W | 0   | 0   | 0   | 0   | 0   | 0  | 0  | AT17 | AT16 | AT15 | AT14 | AT13 | AT12 | AT11 | AT10 |
| ⋮          |     |     |     |     |     |     |    |    |      |      |      |      |      |      |      |      |
| Register 7 | R/W | 0   | 0   | 0   | 0   | 1   | 1  | 1  | AT87 | AT86 | AT85 | AT84 | AT83 | AT82 | AT81 | AT80 |

### R/W

### Read/Write Mode Select

When R/W = 0, a write operation is performed. When R/W = 1, a read operation is performed.

### ATxy

### Digital Attenuation Level Setting

### :PCM/DSD Mode

Where x = register number + 1 and y = 1 to 8, corresponding to the DAC output  $V_{OUT1}$  to  $V_{OUT8}$ . In PCM mode, the default value, 1111 1111b, represents 0 dB. Each DAC channel ( $V_{OUT1}$  to  $V_{OUT8}$ ) includes a digital attenuation function. The attenuation level can be set from 0 dB to –119.5 dB in 0.5 dB steps or to  $-\infty$  in PCM mode, and from 6 dB to –113.5 dB or to  $-\infty$  in DSD mode. Alternatively, the attenuation level can be set to infinite attenuation (or mute). The following table shows attenuation levels for various settings.

| ATxy       | DECIMAL VALUE | ATTENUATION LEVEL SETTING      |           |
|------------|---------------|--------------------------------|-----------|
|            |               | PCM Mode                       | DSD Mode  |
| 1111 1111b | 255           | 0 dB, no attenuation (default) | 6 dB      |
| 1111 1110b | 254           | –0.5 dB                        | 5.5 dB    |
| 1111 1101b | 253           | –1 dB                          | 5 dB      |
| ⋮          | ⋮             | ⋮                              | ⋮         |
| 1111 0011b | 243           | –6 dB                          | 0 dB      |
| 1111 0010b | 242           | –6.5 dB                        | –0.5 dB   |
| ⋮          | ⋮             | ⋮                              | ⋮         |
| 1000 0011b | 131           | –62 dB                         | –56 dB    |
| 1000 0010b | 130           | –62.5 dB                       | –56.5 dB  |
| 1000 0001b | 129           | –63 dB                         | –57 dB    |
| 1000 0000b | 128           | –63.5 dB                       | –57.5 dB  |
| ⋮          | ⋮             | ⋮                              | ⋮         |
| 0111 0101b | 117           | –69 dB                         | –63 dB    |
| ⋮          | ⋮             | ⋮                              | ⋮         |
| 0001 0000b | 16            | –119.5 dB                      | –113.5 dB |
| 0000 1111b | 15            | $-\infty$                      | $-\infty$ |
| ⋮          | ⋮             | ⋮                              | ⋮         |
| 0000 0000b | 0             | $-\infty$                      | $-\infty$ |

|            | B15 | B14 | B13 | B12 | B11 | B10 | B9 | B8 | B7   | B6   | B5   | B4   | B3   | B2   | B1   | B0   |
|------------|-----|-----|-----|-----|-----|-----|----|----|------|------|------|------|------|------|------|------|
| Register 8 | R/W | 0   | 0   | 0   | 1   | 0   | 0  | 0  | MUT8 | MUT7 | MUT6 | MUT5 | MUT4 | MUT3 | MUT2 | MUT1 |

### R/W

### Read/Write Mode Select

When R/W = 0, a write operation is performed. When R/W = 1, a read operation is performed.

### MUTx

### Soft Mute Control

### :PCM/DSD Mode

Where x = 1 to 8, corresponding to the DAC output  $V_{OUT1}$  to  $V_{OUT8}$ . Default value: 0

|          |                         |
|----------|-------------------------|
| MUTx = 0 | Mute disabled (default) |
| MUTx = 1 | Mute enabled            |

The mute bits, MUT1 to MUT8, are used to enable or disable the soft mute function for the corresponding DAC outputs,  $V_{OUT1}$  to  $V_{OUT8}$ . The soft mute function is incorporated into the digital attenuators. When mute is disabled (MUTx = 0), the attenuator and DAC operate normally. When mute is enabled by setting MUTx = 1, the digital attenuator for the corresponding output is decreased from the current setting to infinite attenuation, one attenuator step (0.5 dB) at a time. This provides pop-free muting of the DAC output. By setting MUTx = 0, the attenuator is incremented one step at a time to the previously programmed attenuation level.

|            | B15 | B14 | B13 | B12 | B11 | B10 | B9 | B8 | B7   | B6   | B5   | B4   | B3   | B2   | B1   | B0   |
|------------|-----|-----|-----|-----|-----|-----|----|----|------|------|------|------|------|------|------|------|
| Register 9 | R/W | 0   | 0   | 0   | 1   | 0   | 0  | 1  | DAC8 | DAC7 | DAC6 | DAC5 | DAC4 | DAC3 | DAC2 | DAC1 |

**R/W Read/Write Mode Select**

When R/W = 0, a write operation is performed. When R/W = 1, a read operation is performed.

**DACx DAC Operation Control :PCM/DSD Mode**

Where x = 1 to 8, corresponding to the DAC output  $V_{OUT1}$  to  $V_{OUT8}$ . Default value: 0

|          |                                 |
|----------|---------------------------------|
| DACx = 0 | DAC operation enabled (default) |
| DACx = 1 | DAC operation disabled          |

The DAC operation controls are used to enable and disable the DAC outputs,  $V_{OUT1}$  to  $V_{OUT8}$ . When DACx = 0, the corresponding output generates the audio waveform dictated by the data present on the DATA pin. When DACx = 1, the corresponding output is set to the bipolar zero level, or  $V_{CC} / 2$ . In the TDMCA mode, the DACx bits are affected after the next PLRCK when the write operation occurs.

|             | B15 | B14 | B13 | B12 | B11 | B10 | B9 | B8 | B7  | B6  | B5  | B4  | B3   | B2   | B1   | B0   |
|-------------|-----|-----|-----|-----|-----|-----|----|----|-----|-----|-----|-----|------|------|------|------|
| Register 10 | R/W | 0   | 0   | 0   | 1   | 0   | 1  | 0  | RSV | FLT | ATS | RSV | CKCE | FMT2 | FMT1 | FMT0 |

**R/W Read/Write Mode Select**

When R/W = 0, a write operation is performed. When R/W = 1, a read operation is performed.

**RSV Reserved Bit**

The RSV bit must be set to 0.

**FLT Digital Filter Roll-Off Control :PCM Mode**

Default value: 0

|         |                         |
|---------|-------------------------|
| FLT = 0 | Sharp rolloff (default) |
| FLT = 1 | Slow rolloff            |

The FLT bit allows the user to select the digital filter rolloff that is best suited to a particular application. Two filter rolloff selections are available: sharp and slow. The filter responses for these selections are shown in the *Typical Performance Curves* section of this data sheet.

**ATS Attenuation Rate Select :PCM/DSD Mode**

Default value: 0

|         |                   |
|---------|-------------------|
| ATS = 0 | $8/f_S$ (default) |
| ATS = 1 | $16/f_S$          |

The ATS bit is used to select the rate at which the attenuator is decremented / incremented during level transitions.

**CKCE Clock Select Control :DSD Mode**

Default value: 0

|          |                                                            |
|----------|------------------------------------------------------------|
| CKCE = 0 | System clock is applied to PSCK in the DSD mode (default). |
| CKCE = 1 | System clock is applied to DSCK in the DSD mode.           |

The CKCE bit selects the system clock source in the DSD mode (PSCK or DSCK). The CKCE bit must be set before the DSD bit in register 12 can be set to 1.

**FMT[2:0] Audio Interface Data Format :PCM Mode**

Default value: 000. The FMT[2:0] bits are used to select the data format for the serial audio interface. The table below shows the available format options.

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| FMT[2:0] | Audio Data Format Select                               |
|----------|--------------------------------------------------------|
| 000      | 24-bit standard format, right-justified data (default) |
| 001      | 20-bit standard format, right-justified data           |
| 010      | 18-bit standard format, right-justified data           |
| 011      | 16-bit standard format, right-justified data           |
| 100      | I <sup>2</sup> S format, 24 bits                       |
| 101      | Left-justified format, 24 bits                         |
| 110      | Reserved                                               |
| 111      | Reserved                                               |

|             | B15 | B14 | B13 | B12 | B11 | B10 | B9 | B8 | B7   | B6   | B5   | B4   | B3   | B2   | B1   | B0   |
|-------------|-----|-----|-----|-----|-----|-----|----|----|------|------|------|------|------|------|------|------|
| Register 11 | R/W | 0   | 0   | 0   | 1   | 0   | 1  | 1  | OVR1 | OVR0 | DMF1 | DMF0 | DM78 | DM56 | DM34 | DM12 |

## R/W Read/Write Mode Select

When R/W = 0, a write operation is performed. When R/W = 1, a read operation is performed.

## OVR[1:0] Delta-Sigma Oversampling Rate Select

Default value: 0

| OVR[1:0] | Oversampling Rate Select     |
|----------|------------------------------|
| 00       | 64× f <sub>S</sub> (default) |
| 01       | 128× f <sub>S</sub>          |
| 1x       | 32× f <sub>S</sub>           |

The OVR[1:0] bits are used to change the oversampling rate of delta-sigma modulation. This function makes it easy to design a post-low-pass filter for any sampling rate.

## DMF[1:0] De-Emphasis Sampling Frequency Select

Default value: 0

| DMF[1:0] | De-Emphasis Sampling Frequency Select |
|----------|---------------------------------------|
| 00       | 44.1 kHz (default)                    |
| 01       | 48 kHz                                |
| 10       | 32 kHz                                |
| 11       | Reserved                              |

The DMF[1:0] bits are used to select the sampling frequency for the digital de-emphasis function when de-emphasis is enabled.

## DMxx De-Emphasis Function Control

Default value: 0

|          |                                         |
|----------|-----------------------------------------|
| DMxx = 0 | De-emphasis function disabled (default) |
| DMxx = 1 | De-emphasis function enabled            |

The DMxx bits are used to enable or disable the digital de-emphasis function of selected channel pairs. Suffix 12, 34, 56, 78 means Channel 1 and 2, 3 and 4, 5 and 6, and 7 and 8 respectively. See the plots shown in the *Typical Performance Curves* section of this data sheet.

|             | B15 | B14 | B13 | B12 | B11 | B10 | B9 | B8 | B7   | B6  | B5   | B4   | B3    | B2    | B1    | B0    |
|-------------|-----|-----|-----|-----|-----|-----|----|----|------|-----|------|------|-------|-------|-------|-------|
| Register 12 | R/W | 0   | 0   | 0   | 1   | 1   | 0  | 0  | SRST | DSD | AZRO | ZREV | DRV78 | DRV56 | DRV34 | DRV12 |



**R/W**                      **Read/Write Mode Select**

When  $R/W = 0$ , a write operation is performed. When  $R/W = 1$ , a read operation is performed.

[illegible]

Default value: 0. This bit is available only in the write mode.

|          |                           |
|----------|---------------------------|
| SRST = 1 | DAC system is reset once. |
|----------|---------------------------|

The SRST bit allows the user to reset DAC system. This function is same as the power-on reset. When the SRST is set to 1, one reset pulse is generated internally. It is not necessary to set SRST to 0.

DSD                      DSD Mode Control                      :PCM/DSD Mode

Default value: 0

|         |                    |
|---------|--------------------|
| DSD = 0 | PCM mode (default) |
| DSD = 1 | DSD mode           |

The DSD bit allows the user to select the operation mode, PCM mode or DSD mode.

|             |                                    |                  |
|-------------|------------------------------------|------------------|
| <b>AZRO</b> | <b>Zero Flag Output Pin Select</b> | <b>:PCM Mode</b> |
|-------------|------------------------------------|------------------|

Default value: 0

|          |                                                                                                                                                                                                                                                       |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| AZRO = 0 | When ZREV = 0 and either the channel 1 or channel 2 data is continuously zero, the ZERO1 and ZERO2 pins go HIGH. When ZREV = 1 and either the channel 1 or channel 2 data is continuously zero, the ZERO1 and ZERO2 pins go LOW (default).            |
| AZRO = 1 | When ZREV = 0 and both the channel 1 and channel 2 data is continuously zero, the ZERO1 and ZERO2 pins go HIGH. ZERO2 pin stay in LOW. When ZREV = 1 and both the channel 1 and channel 2 data is continuously zero, the ZERO1 and ZERO2 pins go LOW. |

The AZRO bit allows the user to select the output form of ZERO1 and ZERO2.

**ZREV**                  Zero Flag Polarity Select                  :PCM Mode

Default value: 0

|          |                                                |
|----------|------------------------------------------------|
| ZREV = 0 | Zero flag pins HIGH at a zero detect (default) |
| ZREV = 1 | Zero flag pins LOW at a zero detect            |

The ZREV bit allows the user to select the polarity of zero flag pins.

[illegible]

Default value: 0

|           |                         |
|-----------|-------------------------|
| DRVxx = 0 | Normal output (default) |
| DRVxx = 1 | Inverted output         |

The DRVxx bits control output analog signal phase for channel pairs. The xx suffix in the register name designates the channel pair: -12 indicates channels 1 and 2; -34 indicates channels 3 and 4; -56 indicates channels 5 and 6; and -78 indicates channels 7 and 8.

|             | B15 | B14 | B13 | B12 | B11 | B10 | B9 | B8 | B7   | B6   | B5   | B4   | B3   | B2   | B1   | B0   |
|-------------|-----|-----|-----|-----|-----|-----|----|----|------|------|------|------|------|------|------|------|
| Register 13 | R/W | 0   | 0   | 0   | 1   | 1   | 0  | 1  | FS41 | FS40 | FS31 | FS30 | FS21 | FS20 | FS11 | FS10 |
| Register 14 | R/W | 0   | 0   | 0   | 1   | 1   | 1  | 0  | FS81 | FS80 | FS71 | FS70 | FS61 | FS60 | FS51 | FS50 |

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### R/W Read/Write Mode Select

When R/W = 0, a write operation is performed. When R/W = 1, a read operation is performed.

### FSxy DSD Filter Select

: DSD Mode

Default value: 00

| FSxy | DSD Filter Select  |
|------|--------------------|
| 00   | Filter 1 (default) |
| 01   | Filter 2           |
| 10   | Filter 3           |
| 11   | Reserved           |

The FSxy bits allow selection of the DSD filter from three kind of filters for each channel. The x suffix in the register name designates the channel, from 1 to 8, for which the filter is being selected. The y suffix in the register name designates the high or low bit of the filter selection value.

|             | B15 | B14 | B13 | B12 | B11 | B10 | B9 | B8 | B7    | B6    | B5    | B4    | B3    | B2    | B1    | B0    |
|-------------|-----|-----|-----|-----|-----|-----|----|----|-------|-------|-------|-------|-------|-------|-------|-------|
| Register 16 | R   | 0   | 0   | 1   | 0   | 0   | 0  | 0  | ZERO8 | ZERO7 | ZERO6 | ZERO5 | ZERO4 | ZERO3 | ZERO2 | ZERO1 |

### R Read Only

### ZEROx Zero Flag

|           |                                      |
|-----------|--------------------------------------|
| ZEROx = 0 | Not zero detected on indexed channel |
| ZEROx = 1 | Zero detected on indexed channel     |

The ZEROx bits indicate indexed the result of ZERO detection circuit of each channels.

|             | B15 | B14 | B13 | B12 | B11 | B10 | B9 | B8 | B7  | B6  | B5  | B4  | B3  | B2  | B1  | B0  |
|-------------|-----|-----|-----|-----|-----|-----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|
| Register 17 | R   | 0   | 0   | 1   | 0   | 0   | 0  | 1  | RSV | RSV | RSV | ID4 | ID3 | ID2 | ID1 | ID0 |

### R Read Only

### RSV Reserve Bit

The RSV bit is read as 0.

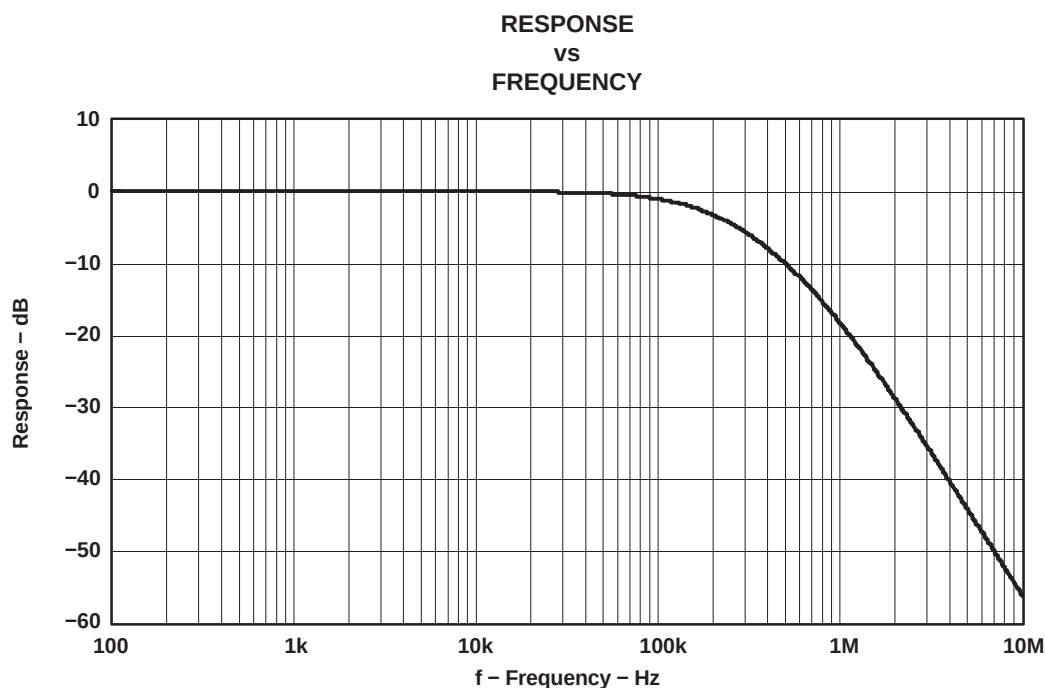
### ID[4:0] Device ID

The ID[4:0] bits show a device ID in TDMCA mode.

## ANALOG OUTPUTS

The DSD1608 includes eight independent output channels:  $V_{OUT1}$  to  $V_{OUT8}$ . These are unbalanced outputs, each capable of driving 4 Vp-p typical into a 10-k $\Omega$  ac-coupled load. The internal output amplifiers for  $V_{OUT1}$  to  $V_{OUT8}$  are biased to the dc common-mode (or bipolar zero) voltage, equal to  $V_{CC}/2$ .

The output amplifiers include an RC continuous-time filter, which helps to reduce the out-of-band noise energy present at the DAC outputs due to the noise shaping characteristics of the DSD1608 delta-sigma D/A converters. The frequency response of this filter is shown in Figure 30. By itself, this filter is not enough to attenuate the out-of-band noise to an acceptable level for many applications. An external low-pass filter is required to provide sufficient out-of-band noise rejection. Further discussion of DAC post-filter circuits is provided in the *Applications Information* section of this data sheet.



**Figure 30. Analog Output Filter Performance (100 Hz–10 MHz)**

## ZERO FLAGS

The DSD1608 includes circuitry for detecting an all-zero data condition for the audio data input pin and output pins for indicating the result.

### Zero Detect Condition

Zero detection for each channel or combination of channels is independent from any other.

In PCM mode, if the data for a given channel or channel combination remains at a 0 level for 1024 sample periods (or PLRCK clock periods), a zero-detect condition exists for that channel or combination of channels.

In DSD mode, zero detection is not available.

### Zero Output Flags

Given that a zero-detect condition exists for each channel or combination of channels, the zero flag pins for those conditions will be set to a logic 1 state. There are three zero flag pins for channel 1, ZERO1 (pin 6), for channel 2, ZERO2 (pin 7) and for a logical AND of channels 3 through 8, ZERO38 (pin 8). These pins can be used to operate external mute circuits, or used as status indicators for a microcontroller, audio signal processor, or other digitally controlled circuit.

The active polarity of the zero flag outputs can be inverted by setting the ZREV bit of control register 12 to 1. The reset default is active-high output, or ZREV = 0.

---

## APPLICATION INFORMATION

### CONNECTION DIAGRAMS

A basic connection diagram is shown in Figure 31, with the necessary power supply bypass and decoupling components.

The use of series resistors ( $22\ \Omega$  to  $100\ \Omega$ ) is recommended for the xSCK, PLRCK, xBCK, PDATAx, and DSDx inputs. The series resistor combines with the stray PCB and device input capacitance to form a low-pass filter which reduces high-frequency noise emissions and helps to dampen glitches and ringing present on clock and data lines.

### POWER SUPPLIES AND GROUNDING

The DSD1608 requires a 5-V analog supply and a 3.3-V digital supply. The 5-V supply is used to power the DAC analog and output filter circuitry, while the 3.3-V supply is used to power the digital filter and serial interface circuitry. For best performance, the 3.3-V digital supply should be derived from the 5-V supply by using a linear regulator. Texas Instruments' REG1117-3.3 is an ideal choice for this application.

Proper power supply bypassing is shown in Figure 31. The  $10\text{-}\mu\text{F}$  capacitors should be tantalum or aluminum electrolytic, while the  $0.1\text{-}\mu\text{F}$  capacitors are ceramic (the X7R type is recommended for surface-mount applications).

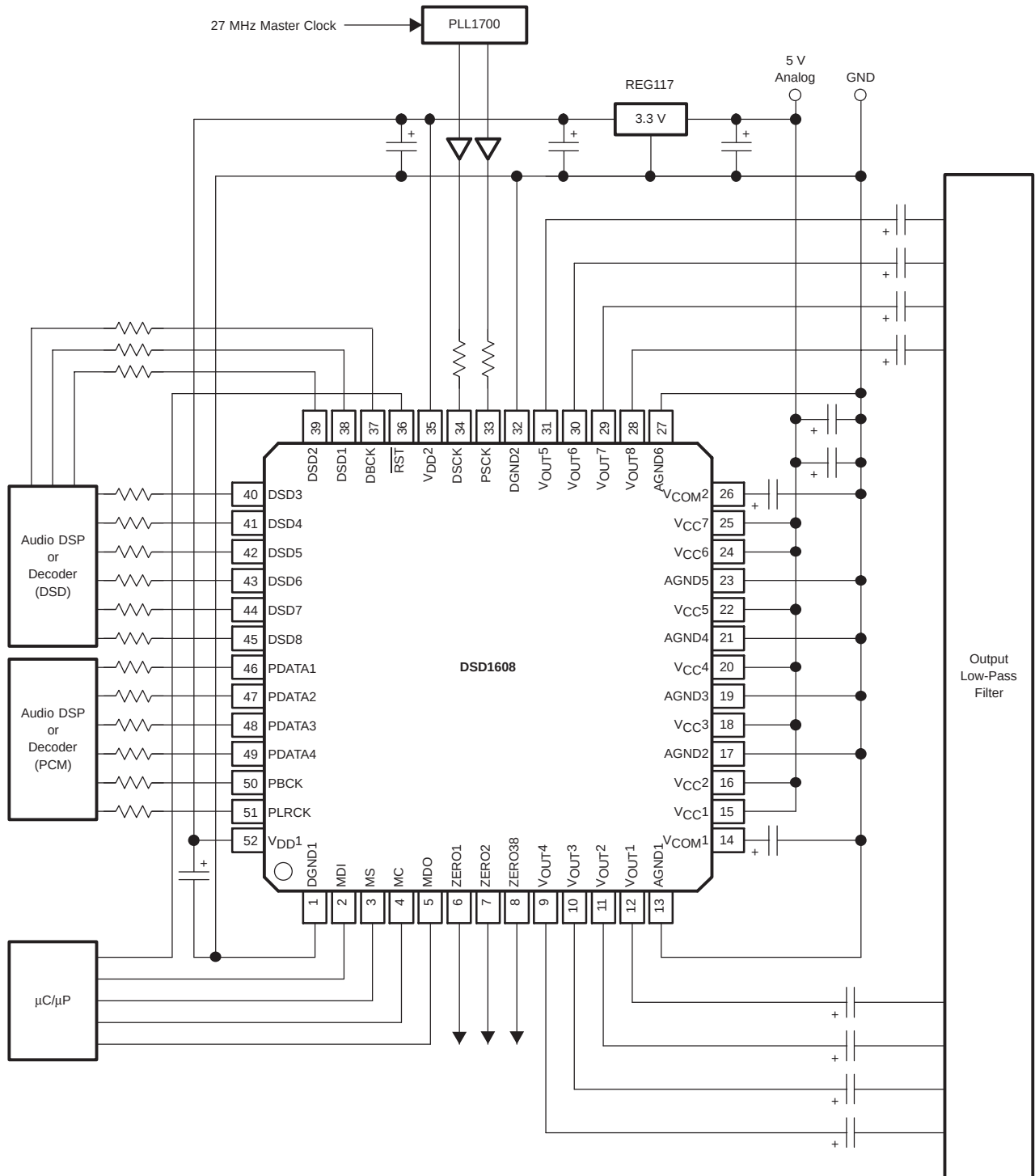


Figure 31. Basic Connection Diagram

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### D/A OUTPUT FILTER CIRCUITS: POST-LOW-PASS FILTER

The DSD1608 requires a third- or second-order analog low-pass filter to achieve the frequency response recommended by the SACD standard and reduce the out-of-band noise produced by the delta-sigma modulator. Figure 32 shows the recommended external low-pass filter circuit. This circuit is a third-order Butterworth filter using the Sallen-Key circuit arrangement. The filter response and corner frequency are determined by the frequency response recommended by the SACD standard. Figure 32 lists the standard values for resistors and capacitors corresponding with the DSD digital filter on DSD1608. This filter can be used in either the PCM or the DSD modes.

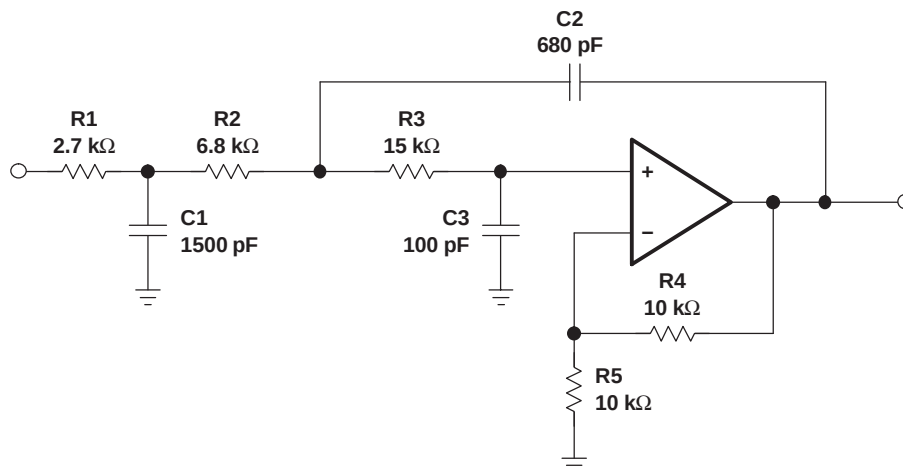


Figure 32. Post-Low-Pass Filter Circuit

### TDMCA FORMAT

The DSD1608 supports the time division multiplexed command and audio data (TDMCA) format to reduce any host control serial interface. The TDMCA format is designed for not only McBSP of TI DSPs but also any programmable devices. The TDMCA format can transfer not only audio data but also command data so that it can be used with any kind of device that supports the TDMCA format. The TDMCA frame consists of a command field, extended command field, and some audio data fields. The audio data are transported to IN devices (such as DAC) and/or from OUT devices (such as ADC). The DSD1608 is an IN device. PLRCK and PBCK are shared both IN and OUT devices so that the sample frequency must be united in one system. The TDMCA mode supports a maximum of 30 device IDs. The maximum number of audio channel depends on the PBCK frequency.

#### TDMCA Mode Determination

The DSD1608 recognizes the TDMCA mode by receiving PLRCK which pulse width is two PBCK clocks. The DSD1608 goes into the TDMCA after two continuous TDMCA frames. Figure 33 shows the PLRCK and PBCK timing required for the TDMCA mode. Any TDMCA commands can be issued the next TDMCA frame after entering the TDMCA mode. If operation in the TDMCA mode operation is not required, PLRCK must be a 50%-duty-cycle square wave.

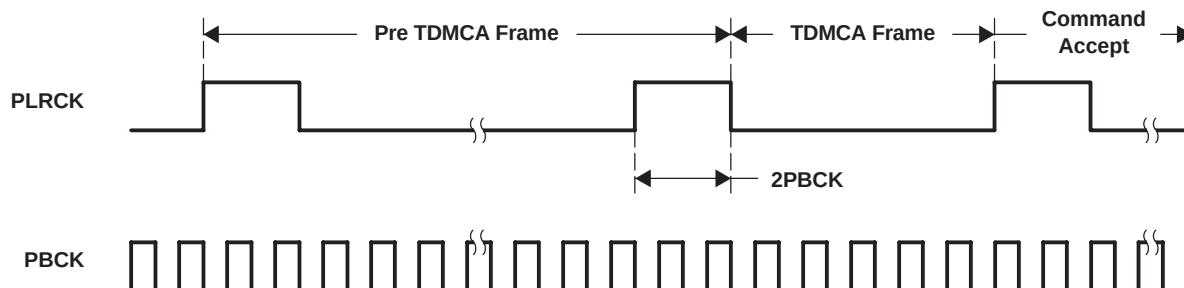


Figure 33. PLRCK and PBCK Timing for the TDMCA Mode

TDMCA requires six signals, of which four are for command and audio data interface and two are for the daisy chain. Signals that can be shared are as indicated in the following table. The host interface signals, MS, MC and MDO change to DCI, DCO, and PDO respectively. The MDO signal is 3-state output so that it can be connected directly to other PDO terminals.

## Device ID Determination

The TDMCA mode also supports a multi-chip implementation in one system. This means that the host controller (DSP) can support several PCM devices and/or other devices simultaneously. The PCM devices are categorized as IN device, OUT device, IN/OUT device, and NO device. The IN device has an input port to receive audio data. The OUT device has a output port to provide audio data. The IN/OUT device has both input and output ports for audio data. The NO device has no port for audio data but needs command data from the host. A DAC is an IN device, an ADC is an OUT device, a CODEC is an IN/OUT device, and a PLL is a NO device. The DSD1608 is an IN device. To distinguish devices from the host controller, each device is given its own device ID by the daisy chain. A device gets its own device ID automatically by connecting its DCO to the DCI of the next device in the daisy chain. There are actually two completely independent and equivalent daisy chains, which are categorized as the IN chain and the OUT chain. Figure 34 shows the daisy chain connection. If a system needs to chain a DSD1608 and a NO device in the same IN chain, the NO device should be chained at the back of the IN chain because it doesn't require any audio data. Figure 35 shows an example of a TDMCA system that includes an IN chain and an OUT chain with a TI DSP. For chained devices to get their own device IDs, the DID signal should be set to 1 (the details are described later) and PLRCK and PBCK should be driven to initiate the TDMCA mode for all devices which are chained. The device at the top of the chain determines its device ID is 1 when DCI is fixed HIGH. Every other device determines its position in the chain by counting PBCK pulses and observing its own DCI signal. Figure 36 shows the initialization of each device ID. If all devices do not need separate device IDs, each DCI should be held high, causing the corresponding device IDs to be 1.



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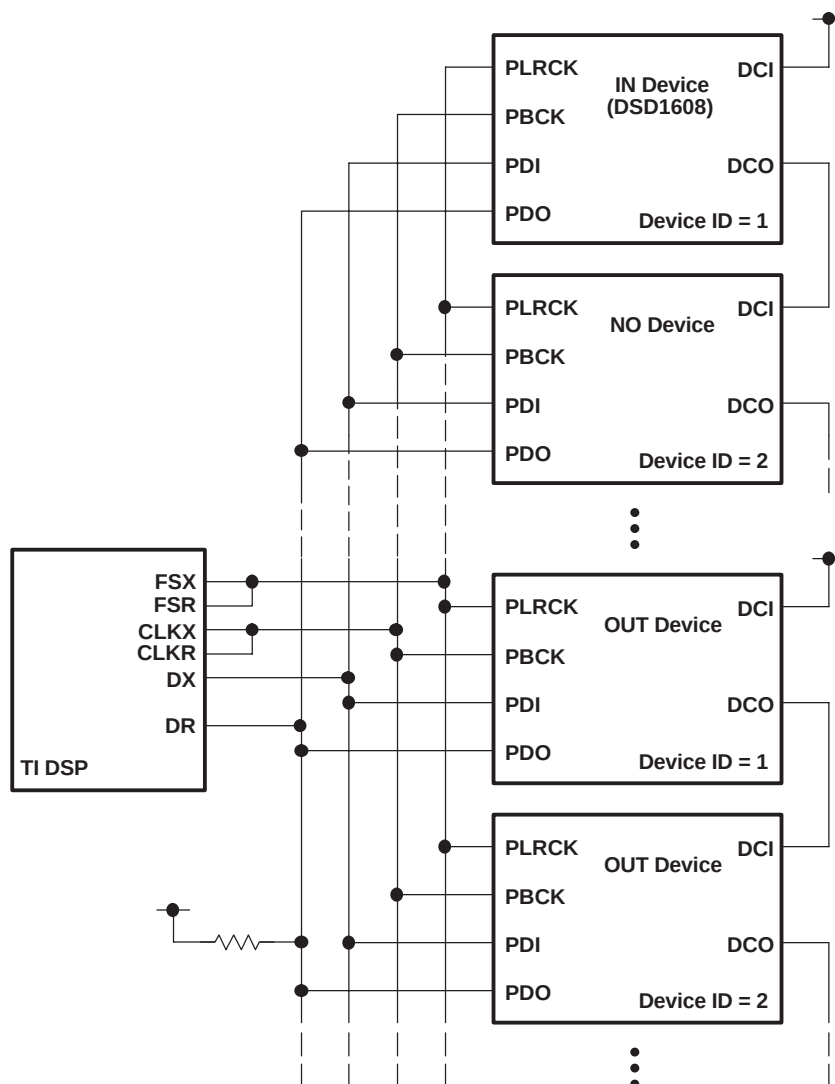


Figure 35. IN and OUT Daisy Chain Connection for Multichip System

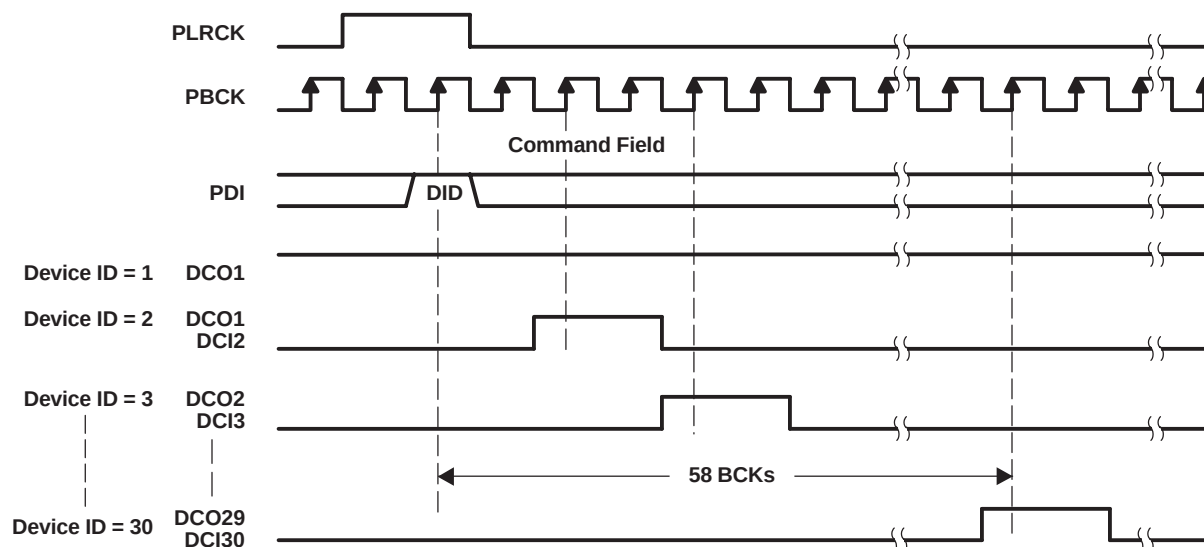


Figure 36. Device ID Determination Sequence



## TDMCA Frame

In general, the TDMCA frame consists of a command field, an extended command (EMD) field, and an audio data field. All fields are 32 bits in length, but the LS byte has no meaning. The MSB is transferred first for each field. The command field is always transferred as the first packet of the frame. The EMD field is transferred if the EMD flag of the command field is high. If any EMD packets are transferred, no audio data follow after those EMD packets. This frame is for quick initialization. All devices of the daisy chain should respond to the command field and extended command field. The DSD1608 has eight audio channels that can be selected in register 41. If the corresponding flags are preset low, those audio channels are transferred. Figure 37 shows a general TDMCA frame. If some DACs are enabled although the corresponding audio data packets are not transferred, the analog outputs of those DACs are unpredictable.

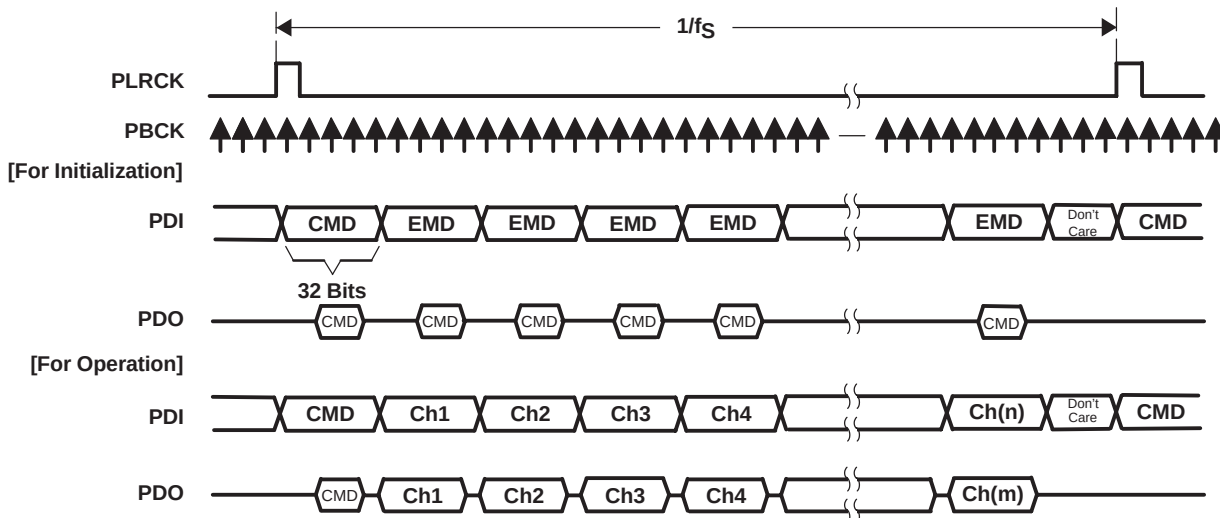


Figure 37. General TDMCA Frame

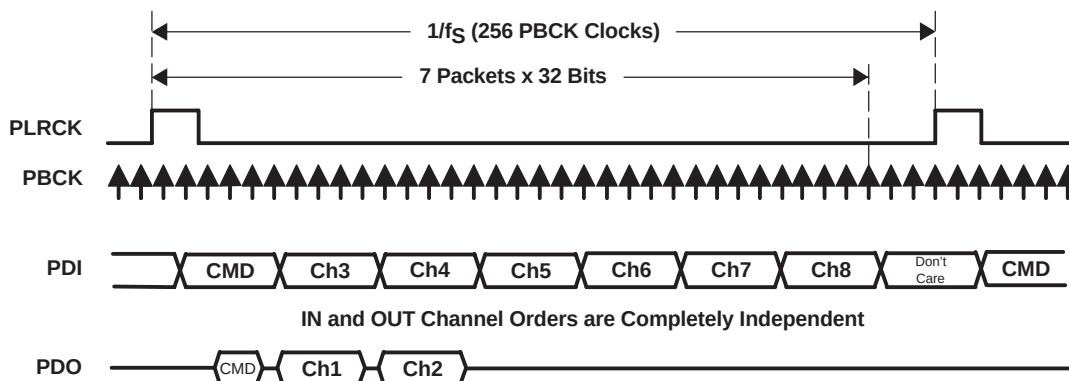


Figure 38. TDMCA Frame Example of 6-Ch DAC and 2-Ch ADC With Command Read

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### Command Field

The command field is defined as follows. The DID field (MSB) has another meaning, that this frame is for device ID determination.

|         |     |     |     |           |     |             |      |          |    |    |   |   |   |
|---------|-----|-----|-----|-----------|-----|-------------|------|----------|----|----|---|---|---|
| 31      | 30  | 29  | 28  | 24        | 23  | 22          | 21   | 20       | 16 | 15 | 8 | 7 | 0 |
| command | DID | EMD | DCS | Device ID | R/W | Register ID | Data | Not used |    |    |   |   |   |

#### Bit 31: Device ID Enable Flag

The DSD1608 operates to get its own device ID if this bit is HIGH. This is for TDMCA initialization.

#### Bit 30: Extended Command Enable Flag

An EMD packet is transferred if this bit is HIGH, otherwise skipped. When the bit is HIGH, this frame does not contain any audio data. This is for system initialization.

#### Bit 29: Daisy Chain Selection Flag

HIGH means OUT chain devices, LOW means IN chain devices. The DSD1608 is an IN device, so the DCS bit must be set to LOW.

#### Bit [28:24]: Device ID

The device ID is 5 bits in length, and it can be defined. IDs of devices follow the order of an IN or OUT daisy chain. The top device of the daisy chain has device ID 1 and the next device in the chain has device ID 2, etc. The ID for any device that has its DCI set HIGH is also 1. The maximum device ID each in the IN or OUT chain is 30. If a device ID is 0x1F, all devices are selected as broadcast when in the write mode. If any device ID is 0x00, no device is selected.

#### Bit 23: Command Read/Write Flag

If it is HIGH, the command is a read operation.

#### Bit [22:16]: Register ID

The register ID is 7 bits in length. See Table 3.

#### Bit [15:8]: Command Data

The command data is 8 bits in length. Any valid data can be chosen for each register. See Table 3.

#### Bit [7:0]: Not used

These bits are never transported when a read operation is performed.

### Extended Command Field

The extended command field is almost the same as the command field. The only difference is that it does not have a DID flag.

|                  |      |     |     |           |     |             |      |          |    |    |   |   |   |
|------------------|------|-----|-----|-----------|-----|-------------|------|----------|----|----|---|---|---|
| 31               | 30   | 29  | 28  | 24        | 23  | 22          | 21   | 20       | 16 | 15 | 8 | 7 | 0 |
| Extended command | RSVD | EMD | DCS | Device ID | R/W | Register ID | Data | Not Used |    |    |   |   |   |

### Audio Field

The audio field is 32 bits in length and the audio data is transferred MSB first. When transferring audio data of less than 32 bits, the unused portion of the field must be padded with 0s, as the following figure shows.

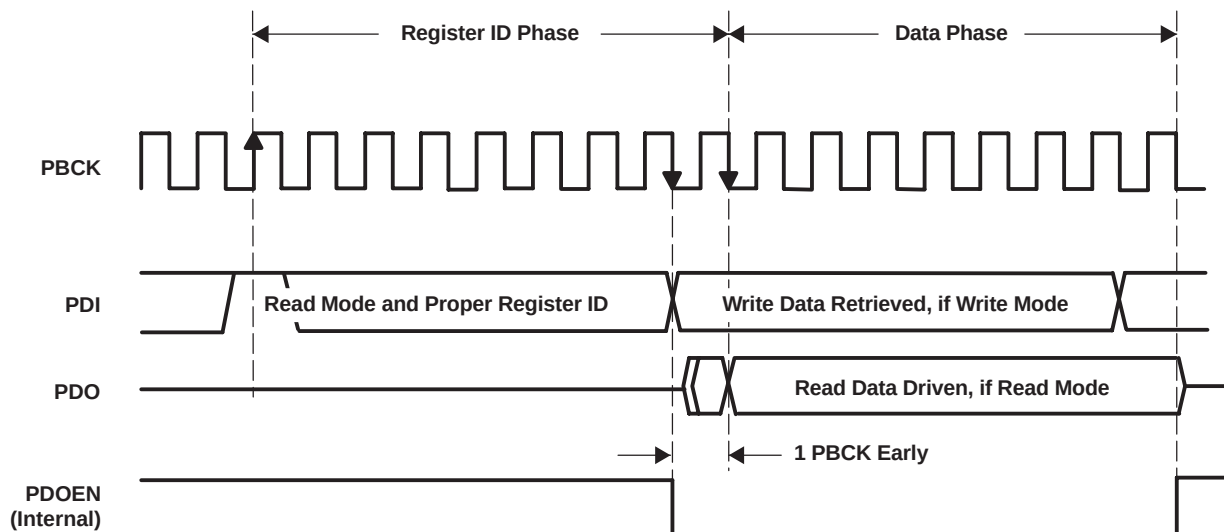
|            |     |         |     |        |   |
|------------|-----|---------|-----|--------|---|
| 31         | 16  | 12      | 8   | 7      | 0 |
| Audio data | MSB | 24 bits | LSB | All 0s |   |
|            | MSB | 20 bits | LSB | All 0s |   |
|            | MSB | 16 bits | LSB | All 0s |   |

### TDMCA Register Requirements

The TDMCA mode requires device ID and audio channel information, previously described. Register 9 indicates the audio channels and register 17 indicates the device ID. Register 17 is used only in the TDMCA mode. See the *Mode Control Register Map*, Table 3.

## Register Write/Read Operation

The command supports register write and read operations. If the command requests to read one register, the read data is transferred on PDO during the data phase portion of the timing cycle. The PDI signal can be retrieved on the positive edge of PBCK and the PDO signal is driven on the negative edge of PBCK. The PDO is activated one cycle early due to compensate for the output delay caused by high impedance. Figure 39 shows the TDMCA write and read timing.



**Figure 39. TDMCA Write and Read Operation Timing**

## TDMCA Mode Operation

DCO specifies the owner of the next audio channel in TDMCA operation. When one device retrieves its own audio channel data, the DCO becomes HIGH during last audio channel period. Figure 40 shows the DCO output timing during a TDMCA-mode operation. The host controller is not affected by the behavior of DCI and DCO. DCO indicates the last audio channel of each device. Therefore, DCI means that the next audio channel is allocated.

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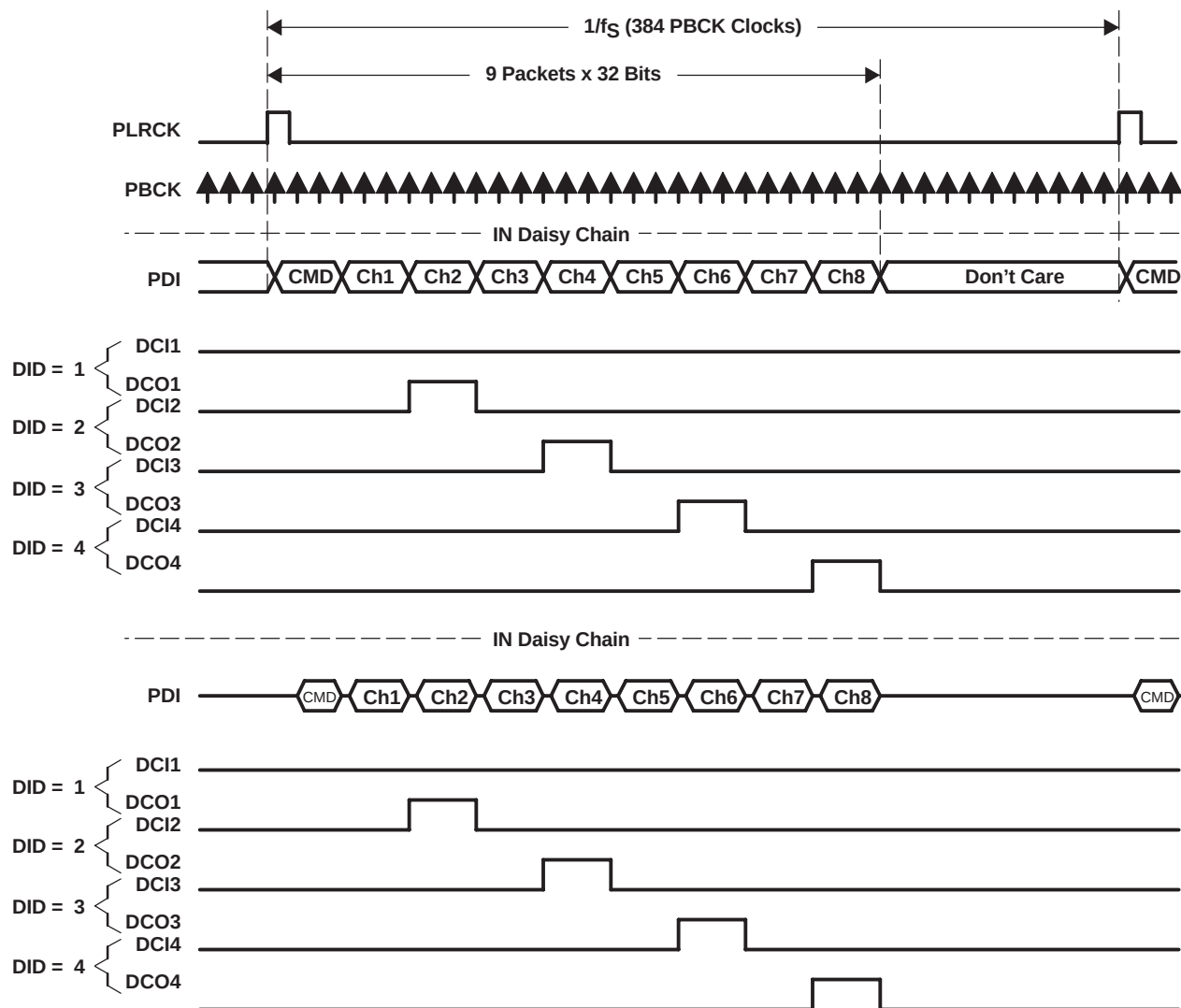


Figure 40. DCO Output Timing in TDMCA-Mode Operation

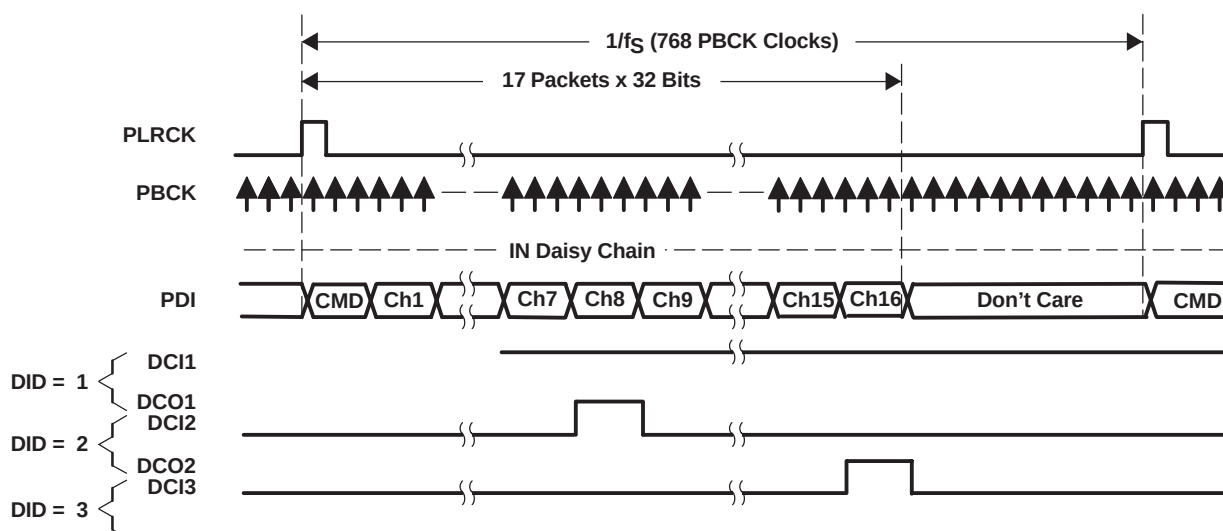


Figure 41. DCO Output Timing Example for 16-Ch Audio Data of Two DSD1608s

If some devices are skipped due to lack of an active audio channel, each skipped device must notify the next device that the DCO will be passed through the next DCI. Figure 42 and Figure 43 show DCO timing with skip operation. Figure 44 shows the ac timing of daisy chain signals.

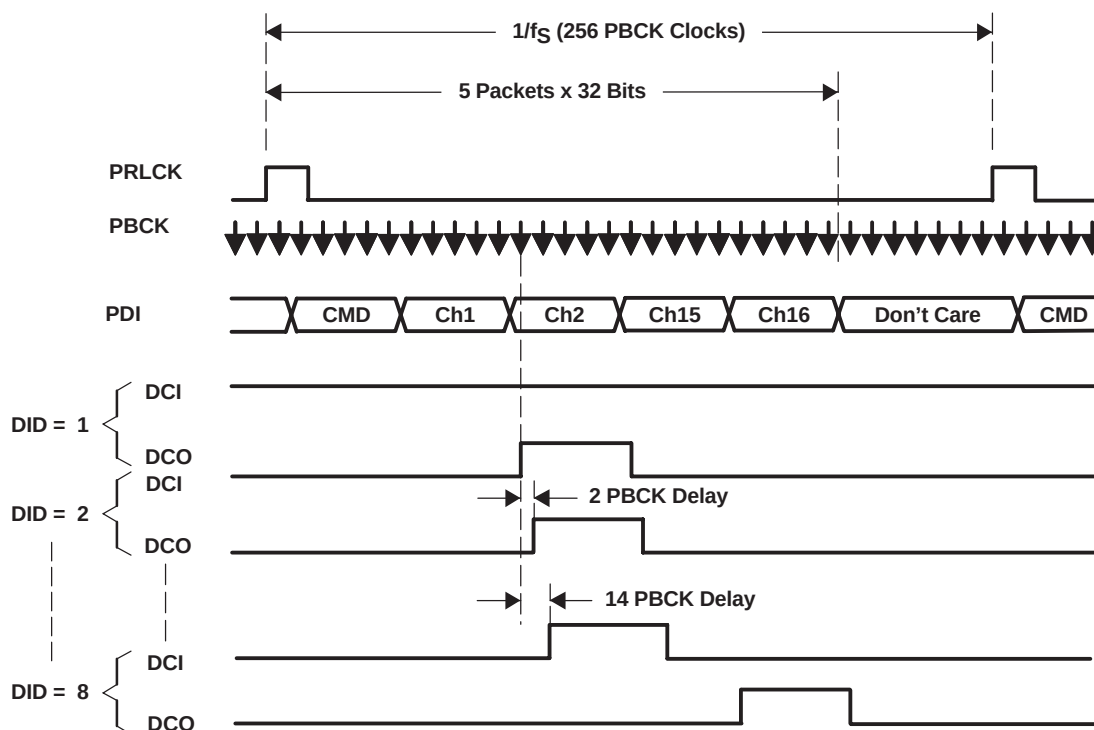


Figure 42. DCO Output Timing With Skip Operation

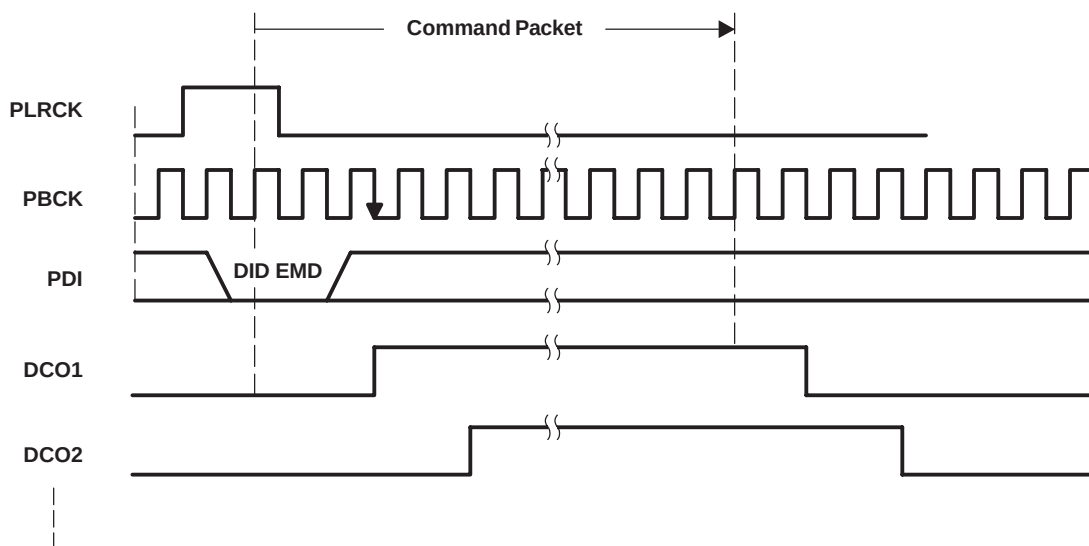
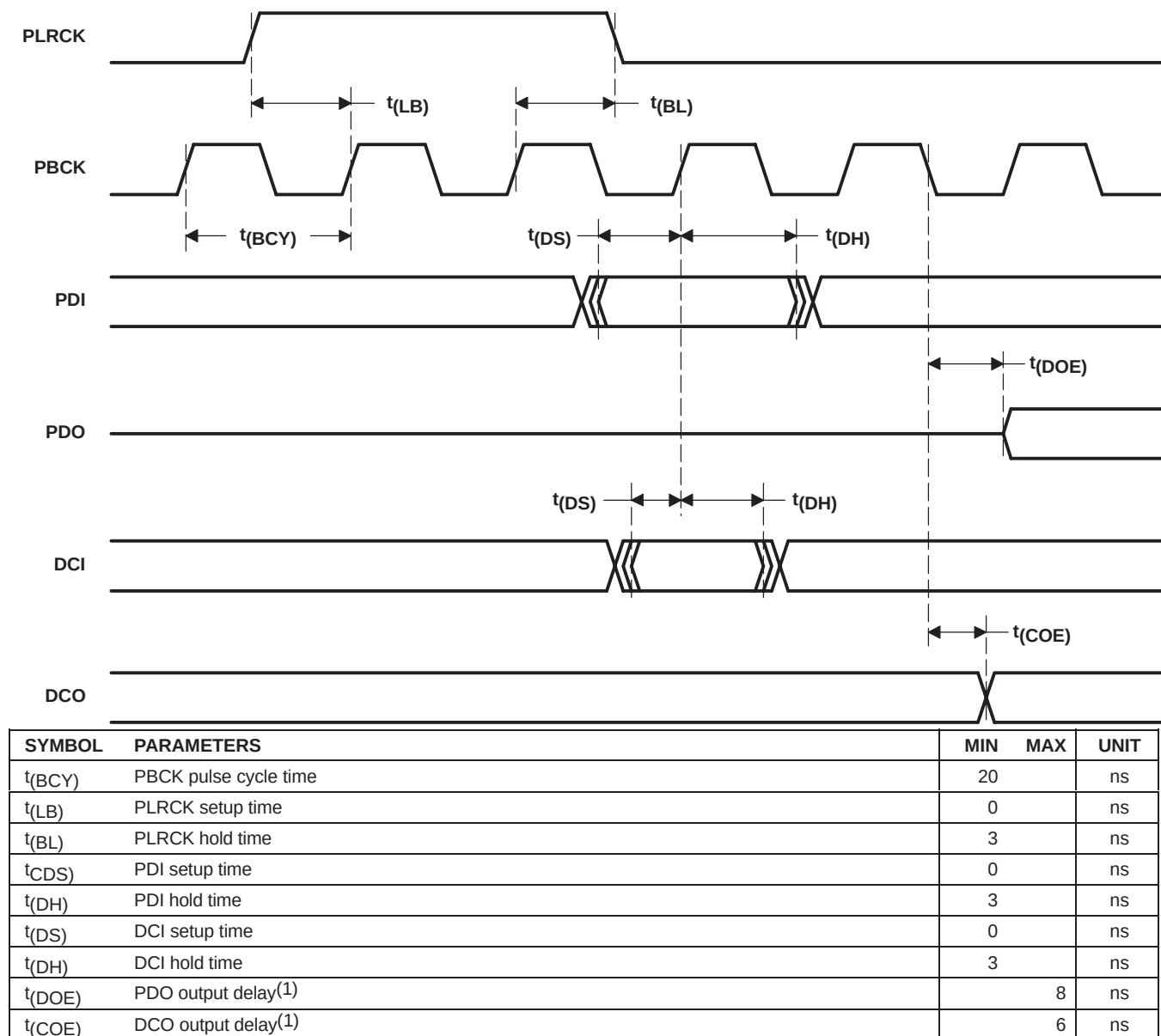


Figure 43. DCO Output Timing With Skip Operation (for Command Packet 1)

## DSD1608

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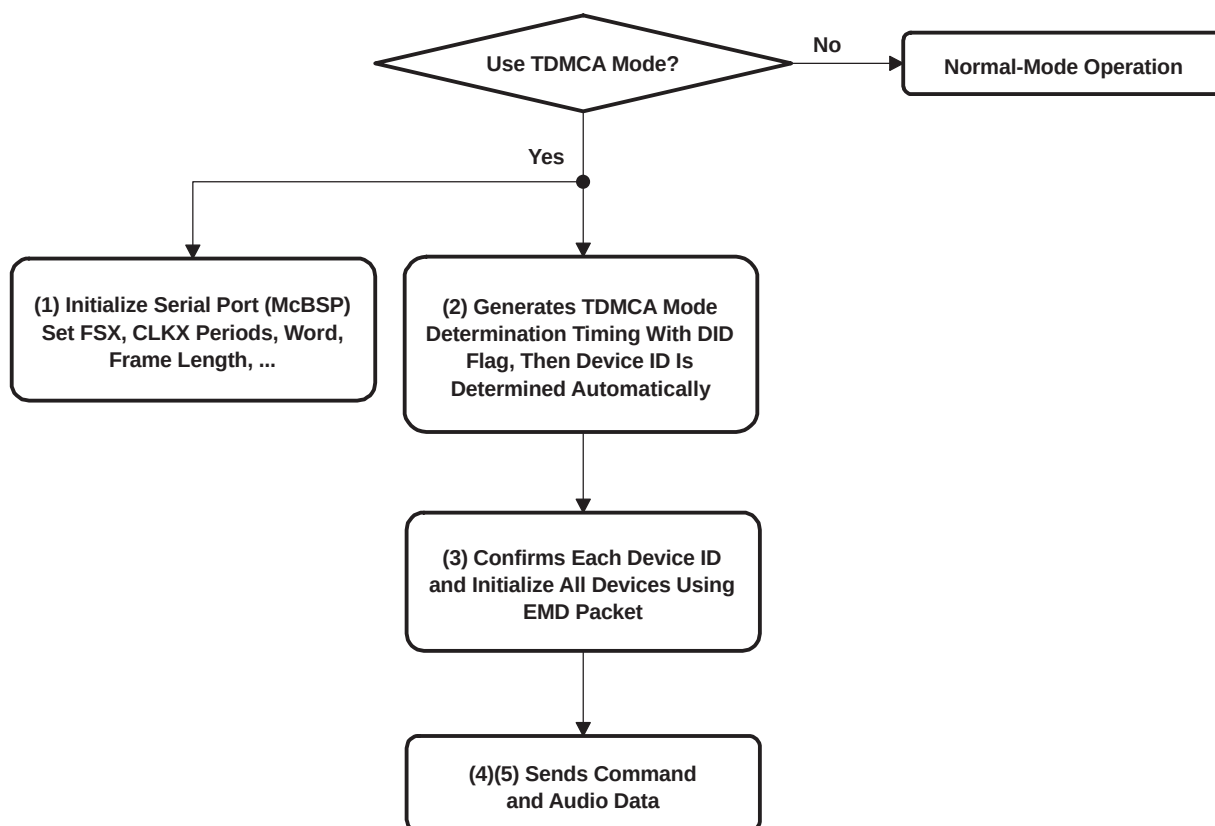
<sup>(1)</sup> Load capacitance is 10 pF.

**Figure 44. AC Timing of Daisy Chain Signals**

## HOST CONTROL FLOW

The host controller can control the TDMCA mode as follows:

1. Decides daisy chain to initialize PLRCK and PBCK signals generator
2. Generates TDMCA mode determination sequence
3. Sets DID flag in command to fix device ID automatically
4. Checks all device IDs if necessary
5. Initializes all devices
6. Communicates audio data and commands



**Figure 45. TDMCA Control Flow From Host**

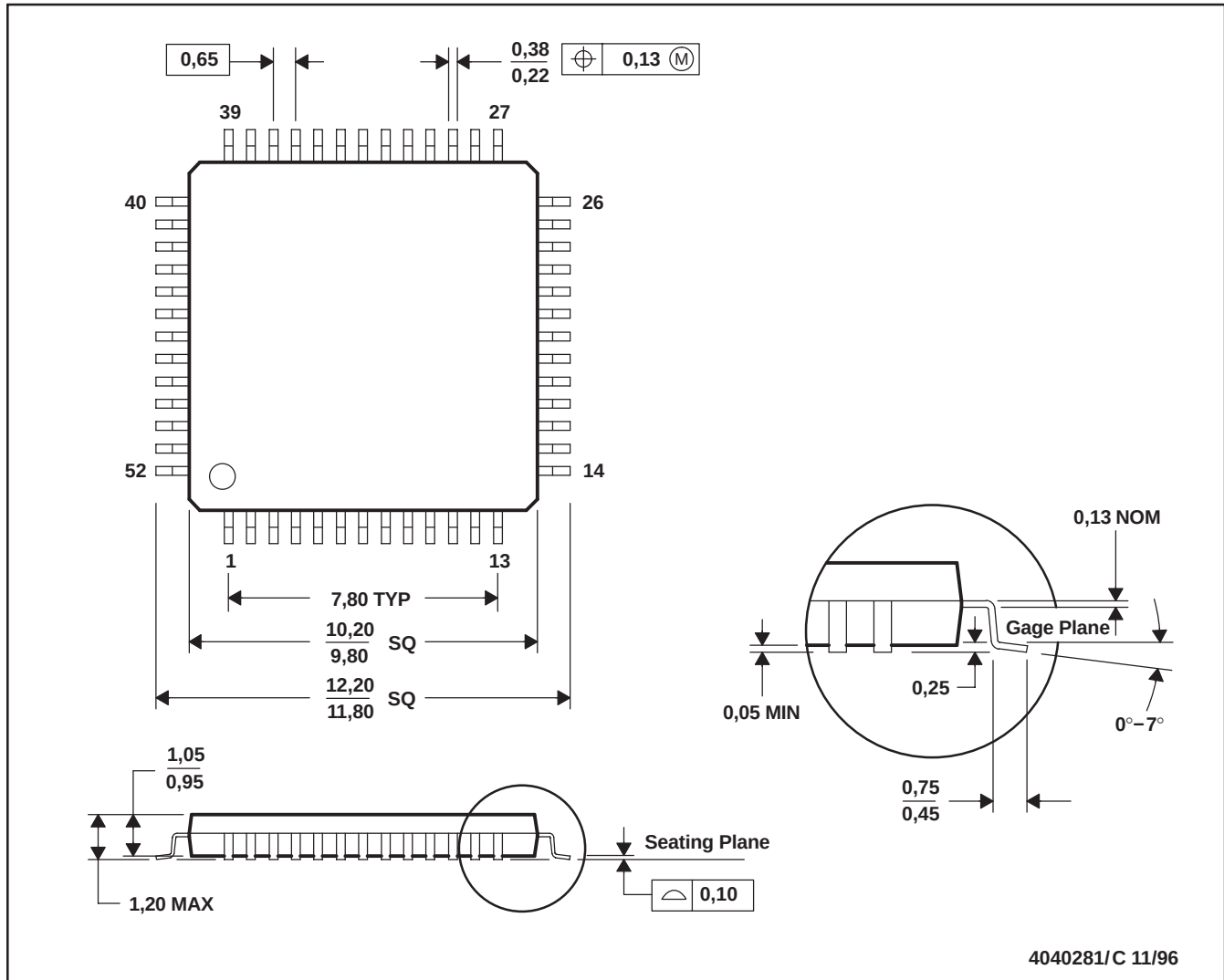
# DSD1608

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## MECHANICAL DATA

PAH (S-PQFP-G52)

PLASTIC QUAD FLATPACK



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Falls within JEDEC MS-026



## PACKAGING INFORMATION

| Orderable Device | Status <sup>(1)</sup> | Package Type | Package Drawing | Pins | Package Qty | Eco Plan <sup>(2)</sup> | Lead/Ball Finish | MSL Peak Temp <sup>(3)</sup> |
|------------------|-----------------------|--------------|-----------------|------|-------------|-------------------------|------------------|------------------------------|
| DSD1608PAH       | ACTIVE                | TQFP         | PAH             | 52   | 160         | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-3-260C-168 HR          |
| DSD1608PAHG4     | ACTIVE                | TQFP         | PAH             | 52   | 160         | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-3-260C-168 HR          |
| DSD1608PAHR      | ACTIVE                | TQFP         | PAH             | 52   | 1500        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-3-260C-168 HR          |
| DSD1608PAHRG4    | ACTIVE                | TQFP         | PAH             | 52   | 1500        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-3-260C-168 HR          |

<sup>(1)</sup> The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

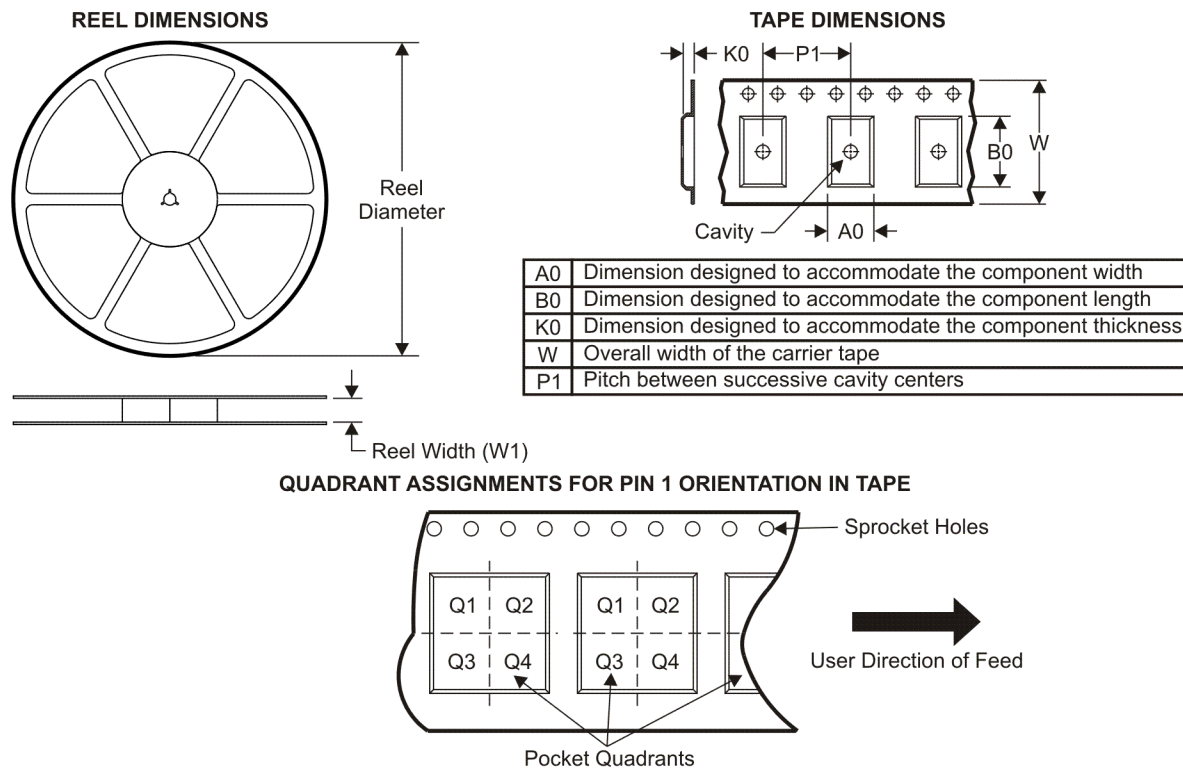
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

<sup>(3)</sup> MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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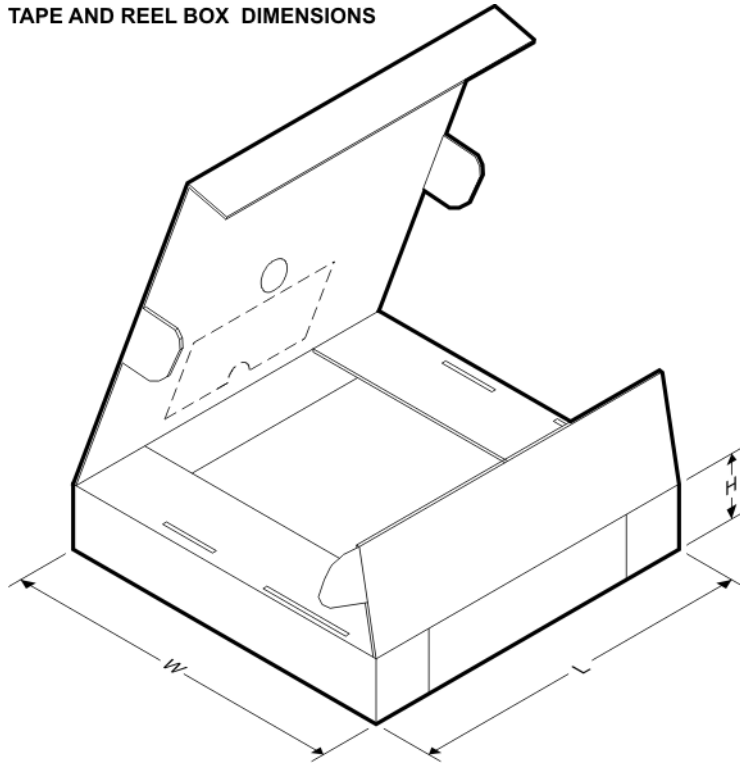
**TAPE AND REEL INFORMATION**



\*All dimensions are nominal

| Device      | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| DSD1608PAHR | TQFP         | PAH             | 52   | 1500 | 330.0              | 25.4               | 12.35   | 12.35   | 1.65    | 16.0    | 24.0   | Q2            |

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device      | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-------------|--------------|-----------------|------|------|-------------|------------|-------------|
| DSD1608PAHR | TQFP         | PAH             | 52   | 1500 | 346.0       | 346.0      | 41.0        |

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| Broadband          | <a href="http://www.ti.com/broadband">www.ti.com/broadband</a>           |
| Digital Control    | <a href="http://www.ti.com/digitalcontrol">www.ti.com/digitalcontrol</a> |
| Medical            | <a href="http://www.ti.com/medical">www.ti.com/medical</a>               |
| Military           | <a href="http://www.ti.com/military">www.ti.com/military</a>             |
| Optical Networking | <a href="http://www.ti.com/opticalnetwork">www.ti.com/opticalnetwork</a> |
| Security           | <a href="http://www.ti.com/security">www.ti.com/security</a>             |
| Telephony          | <a href="http://www.ti.com/telephony">www.ti.com/telephony</a>           |
| Video & Imaging    | <a href="http://www.ti.com/video">www.ti.com/video</a>                   |
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